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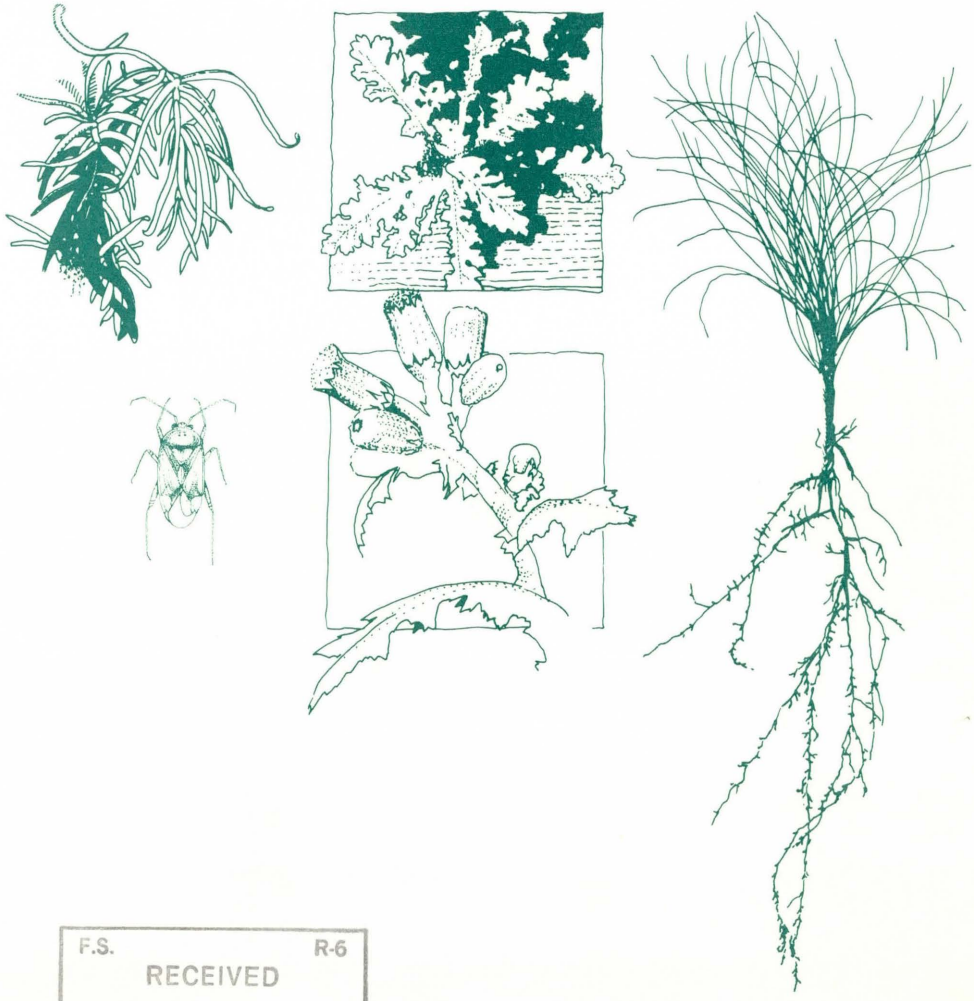
March 1989

Annotated Bibliography

Of Conifer Seedling Pests in Pacific Northwest Bareroot Nurseries

Edited by Robin Rose, Sally Campbell, and Jim Edgren



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Annotated Bibliography

of Conifer Seedling Pests in Pacific Northwest Bareroot Nurseries

Edited by Robin Rose, Sally Campbell, and James Edgren

A Cooperative Project of

Oregon State University
Department of Forest Science
Nursery Technology Cooperative
Corvallis, Oregon 97331

and

USDA Forest Service
Forest Pest Management and
Timber Management
Pacific Northwest Region
Portland, Oregon 97208

March 1989

Introduction

This bibliography was initially prepared as an appendix to an environmental impact statement for pest management in Forest Service nurseries in Oregon and Washington. As such, it includes references for only those pests which have occurred at the four Federal nurseries (Bend Pine Nursery, Dorena Tree Improvement Center, J. Herbert Stone Nursery, and Wind River Nursery) prior to 1988. However, the majority of the insects, diseases, and weeds occurring in Pacific Northwest forest nurseries are included in this bibliography, due to the wide geographical distribution of the four nurseries and the variety of pests found at each.

This bibliography is arranged into three major sections: diseases, insects, and weeds. Each section is further divided into subsections for the general area and for each individual disease or insect. Subsections for individual weeds were not developed; all weed references are in the general weed sub-section, followed by several weed cross-indices. Preceding the annotated references for each pest is a short summary telling the reader how many references for that pest are included, where (geographically) the references come from, and what is reported (e.g., pest biology, control trials, impact assessment, detection survey, etc).

Literature listed for each pest is primarily that originating from British Columbia, Canada, and the northwest portion of the United States: Oregon, Washington, Idaho, Montana, and northern California. If northwest literature is sparse or non-existent, references from a broader geographical area are included. For example, almost no literature was found from the Pacific northwest for the Matsucoccus scale insect; therefore, much of the listed literature is from the northeastern part of the United States, where Matsucoccus scale is common on red pine. Similarly, when there are only a few references dealing with a particular pest on conifer seedlings, references for that pest on non-conifer hosts are used.

We hope that this publication will be useful to you. We feel that it represents a comprehensive source of literature for many northwest nursery pests prior to 1988 and can be used as a good source reference in future years.

Our appreciation is extended to Donna Loucks, Forestry Information Specialist, who did the initial literature search, wrote many of the annotations, and compiled many of the reprints.

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Annotated Bibliography
Diseases

Diseases

General References

We include 11 general disease references in this bibliography. Many of these are compendiums, giving descriptions of symptoms, hosts, geographical distribution, damage, and management for a number of different seedling diseases (1, 4, 5, 7, 8, 10); colored pictures are included in three (1, 7, 10). Three references are discussions of disease management practices (3, 9, 11); one is a listing of fungicides and fumigants which are registered for forest nursery use in the Pacific Northwest (2); and one is a report summarizing the impact of nursery pests in the United States (6).

1. Anonymous. 1983. Forest disease management notes. USDA Forest Service, Pacific Northwest Region.

   A compilation of single page summaries of hosts, recognition, disease spread, management and color photos of various diseases, including damping-off, Fusarium root rot, gray mold, needle cast of larch, Phomopsis canker of Douglas-fir, Phytophthora root rot and western gall rust.

2. Cooley, S.J. 1988. Currently registered fungicides and fumigants for use in forest nurseries in Oregon, Washington, and Idaho. USDA Forest Service, Pacific Northwest Region, Portland, Oregon. Revised March 1988.

   A listing of fungicides and fumigants which are registered for use in Pacific Northwest conifer nurseries. For each product, gives trade name, manufacturer, EPA registration number, crops which are protected according to label, and pests which are controlled according to label.

3. Filer, T.H. and C.E. Cordell. 1987. Integrated pest management in forest nurseries. IN: Intermountain Nursery Association Meeting, Proceedings, p.116-119.

   IPM techniques and procedures provide the necessary information to assist nursery managers in planning the most effective practices to produce quality seedlings. An integrated program that considers the following factors will minimize losses from diseases, insects, and weeds: site selection, fumigation, crop rotation, cover crops, sowing date, fertilization, irrigation, seedbed density, and chemical and biological control methods.

4. Gilmour, J.W. 1966. The pathology of forest trees in New Zealand: the fungal, bacterial, and algal pathogens. New Zealand Forest Service, Forest Research Institute, Technical Report 48.

   Lists pathogens by host trees and discusses effects on hosts by diseases. Includes gray mold, damping-off, Lophodermium needlecast, Phomopsis canker, Phytophthora root rot, larch needlecast. Hosts include ponderosa pine, Douglas-fir, lodgepole pine, and larch.

5. Hepting, G.W. 1971. Diseases of forest and shade trees of the United States. USDA Agriculture Handbook 386.

   Discusses characteristics of seedling and other diseases by host for most trees grown in the United States. Includes crown gall, damping-off, gray mold, Dothistroma needle blight, western gall rust, Fusarium root rot, Lophodermium needle cast, Phomopsis canker, and Phytophthora root rot.

6. Oak, S.W. 1985. Nursery pests: pests may cause 20 percent of seedling mortality. IN: USDA Forest Service, General Technical Report WO-46, p.64-75. Insect and disease conditions in the U.S. 1979-83.

   Summarizes impacts of pests in U.S. forest nurseries. Includes damping-off, western gall rust, Sirococcus tip blight, gray mold, Fusarium root rot, Phytophthora root rot, Dothistroma blight, upper stem canker, and storage mold. Impact is re-

ported by state. Hosts mentioned in the discussion included lodgepole and ponderosa pines.

7. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

   Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Fusarium root rot, Phytophthora root rot, crown gall, Phomopsis canker, Sirococcus tip blight, gray mold, western gall rust, Lophodermium needle cast, Dothistroma needle blight, damping-off and storage molds.

8. Riffle, J.R.and R.S. Smith. 1979. Nursery diseases of western conifers. Forest Insect and Disease Leaflet 157. USDA-Forest Service, 11p.

   Describes briefly some of the more important seedling diseases and suggests general types of control procedures.

9. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p.203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

   A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

10. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

    Reviews hosts, damage, life history and control of various nursery diseases, including damping-off, Fusarium root rot, Sirococcus blight, Fusarium top blight, gray mold, western gall rust, and storage molds.

11. Wall, R.E. 1978. Disease control in forest nurseries. Canadian Forestry Service, Maritimes Forest Research Centre, Report M-X-94.

    Most disease problems in forest nurseries can be prevented by appropriate site selection, careful choice of windbreak species and close attention to other normal management practices. The common diseases in Maritime forest nurseries are briefly described and known factors affecting their incidence are discussed in relation to control. The major control practices are described, including some of the more promising fungicidal treatments. To minimize fungicide use, emphasis is placed on management practices.

Crown Gall

(*Agrobacterium tumefaciens*)

We list a total of 15 references for crown gall, of which 9 deal with the disease on western conifers. The remaining articles are from other parts of the world on coniferous (1) or deciduous tree species (7, 15) or on treefruits, both within and outside the United States (3, 4, 6). Crown gall is reported on species within the Families Cupressaceae (*Juniperus, Cupressus, Libocedrus*), Taxaceae (*Taxus*), Taxodiaceae (*Sequoia*), and Pinaceae (*Pseudotsuga*). The majority of references deal with the biology of the disease, focusing primarily on relative susceptibility of various species of conifers to the disease (1, 9, 10, 11, 12, 13, 14). Four articles discuss management of crown gall by biological means (3, 4) or by a combination of chemical and cultural strategies (5, 8).

1. De Cleene, M. and J. De Ley. 1976. The host range of crown gall. Botanical Review 42(4):389-466.

In current literature, its host range is not clearly defined or is thought to be restricted to the dicotyledonous class of the angiosperms. The susceptibility of 1,193 species belonging to 588 genera and 138 families was reviewed; 643 are host plants belonging to 331 genera and 93 families. The susceptibility of plants to crown gall was correlated with known and/or presumed taxonomic relationships. No lower plant is known to be a host. About 60 percent of the gymnosperms and the dicotyledonous angiosperms examined were sensitive for crown gall. Susceptible monocots are limited to the Liliales and Arales. Thus, the common opinion that the host range of crown gall is restricted to the dicotyledonous plants is incorrect.

2. Hansen, H.N. and R.E. Smith. 1933. A bacterial gall disease of Douglas-fir. Science 77:628.

Report of gall disease of twigs and stems of 3- to 15-year-old Douglas-fir in several California counties. Describes appearance and growth of galls and gives a description of causal bacterium.

3. Kerr, A. 1980. Biological control of crown gall through production of Agrocin 84. Plant Disease 64(1):25-30.

A non-pathogenic strain of *Agrobacterium tumefaciens* has been used to control crown gall disease in a stone fruit nursery. High numbers of the non-pathogenic strain are located near the roots of susceptible plants by inoculation. This non-pathogenic strain, Agrocin 84, is now commercially available for use.

4. Kerr, A. 1972. Biological control of crown gall: seed inoculation. Journal of Applied Bacteriology 35:493-497.

Peach seeds were inoculated with the nonpathogenic isolate 84 of *Agrobacterium radiobacter* var. *radiobacter* biotype 2 before sowing in natural soil heavily inoculated with the tumour inducing biotype 2 isolate 27 (*A. radiobacter* var. *tumefaciens*). Nonpathogens (presumably isolate 84) became predominant in the biotype 2 population on roots, on underground stems and in the soil around plant crowns. Significant ($p < 0.001$) biologi-

cal control of crown gall was achieved. Total gall incidence on plants grown from inoculated seed was 31 percent, and from uninoculated seed, 79 percent; the corresponding gall incidence on plant crowns was 12 percent and 76 percent. Dusting seed with Thiram (3.1 g/kg seed) did not significantly reduce disease incidence. Infection appeared to occur through undamaged lenticels, indicating that wounding is not a necessary prerequisite for crown gall induction in peach.

5. Maloy, O.C. 1981. Crown gall. Washington State University, Cooperative Extension Service, Extension Bulletin 923.

   In Washington, crown gall is most serious on cherries, apples and other tree fruits, but it is also a problem on roses and several other ornamental trees and shrubs. Crown gall is best controlled in orchard and ornamental trees by elimination of infected trees. Nursery soil in which crown gall has occurred may be treated with a suitable fumigant, such as chloropicrin or methyl bromide. Growing a nonsusceptible crop, such as grass, for 3 years, will almost eliminate the organism from the soil.

6. Moore, L.W. 1976. Latent infections and seasonal variability of crown gall development in seedlings of three *Prunus* species. Phytopathology 66:1097-1101.

   Crown gall, caused by *Agrobacterium tumefaciens*, continues to be a serious disease of nursery stock in the Pacific Northwest. In the nursery, eradicants such as Bacticin are not economical for destroying the tumors. Instead, control procedures must be devised to prevent infection. At present, galling is the only criterion signalling infection, thus infection is difficult to predict in time for preventive control measures. The purpose of this study was to determine (1) at what growth stage of the host galls become visible in the field, (2) the time period between inoculation and symptom expression in the field or in winter storage, (3) the influence of soil temperature and moisture on symptom expression, and (4) how long wounds on *Prunus* species remain susceptible to infection during the growing season and in storage.

7. Nesme, X., M.F. Michel, and B. Digat. 1987. Population heterogeneity of *Agrobacterium tumefaciens* in galls of *Populus L.* from a single nursery. Applied and Environmental Microbiology 53(4):655-659.

Soil effects on crown gall frequency in a French nursery plot were detected, indicating that contamination was due to a resident population of the pathogen which was present before the seedlings were planted. The crown gall frequency on poplar progenies varied from 3 to 67 percent, suggesting the feasibility of improvement in crown gall resistance. Of 129 tumour isolates, 128 were pathogenic. These were of biotype 1 or 2. Biochemical, serological and antibiotic resistance typing results concurred, indicating the presence of four biotype 1-resident and biotype 2-resident subpopulations. No significant change was noticed in the relative proportions of subpopulations from one year to another. Pathogenic subpopulations both in vitro and in plants were susceptible to Kerr K84. There were no serological cross-reactions between K84 and the pathogenic subpopulations.

8. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including crown gall.

9. Smith, C.O. 1935. Crown gall on the *Sequoia*. Phytopathology 25:439-440.

An inoculation of *Pseudomonas (Agrobacterium) tumefaciens* isolated from a peach seedlings was made on *Sequoia gigantea* and *S. sempervirens*. About 4 months after inoculation, one gall was observed on *Sequoia gigantea*. Another smaller one was observed in October. The inoculations on *Sequoia sempervirens* were negative after 4 months, with two doubtful inoculations having small enlargements with knot-like outgrowths that may represent the beginnings of galls. The inoculations seem to suggest that sequoias are not immune from but somewhat resistant to the crown gall organism.

10. Smith, C.O. 1935. Crown gall on conifers. Phytopathology 25:894.

    Crown gall produced by artificial inoculation is reported on *Cupressus arizonica, C. lusitanica, C. guadalupensis, C. macrocarpa, C. sempervirens, Chamaecyparis lawsoniana, Juniperus procera, J. cedrus, J. hierbernica, Thuja orientalis, T. plicata, T. occidentalis, Sequoia sempervirens, S. gigantea, Pseudotsuga taxifolia,* and *Libocedrus decurrens.*

11. Smith, C.O. 1937. Crown gall on incense cedar, *Libocedrus decurrens.* Phytopathology 27:844-849.

    The crown gall organism has been isolated from galls on *Libocedrus decurrens.* This culture caused typical crown gall on other hosts: tomato, tobacco, *Salix* spp., *Prunus cerasifera,* and *Cupressus sempervirens.* Galls were produced artificially on *L. decurrens* with cultures from incense cedar, peach and *Salix* spp. Some of these artificial galls on *L. decurrens* are not entirely typical of crown gall as it often develops on susceptible hosts. *L. decurrens,* when growing under cultivation, has been susceptible to crown gall.

12. Smith, C.O. 1942. Crown gall on species of Taxaceae, Taxodiaceae and Pinaceae, as determined by artificial inoculations. Phytopathology 32:1005-1009.

    Inoculations with *Pseudomonas (Agrobacterium) tumefaciens* were made on different species of conifers. Galls developed on the following species: *Podocarpus elongata, Taxus baccata* var. *erecta, T. brevifolia, T. media, Torreya californica, Cunninghamia lanceolata, Sequoia gigantea, S. sempervirens, Sciadopitys verticilata, Abies cephalonica, A. concolor, A. firma,* and *A. holophylla.* No galls were obtained on *Pseudotsuga taxifolia (menziesii), Cedrus deodora, Larix decidua, L. kaempferi,* or on various *Pinus* species.

13. Smith, C.O. 1938. Crown gall on *Taxus baccata.* Phytopathology 28:153-155.

    Crown gall produced by artificial inoculation is reported for European yew, *Taxus baccata* var. *erecta. Pseudomonas*

(*Agrobacterium*) *tumefaciens* isolates used for inoculations were from *Prunus persica* and *Libocedrus decurrens.*

14. Smith, C.O. 1939. Susceptibility of species of Cupressaceae to crown gall as determined by artificial inoculation. Journal of Agricultural Research 59:919-925.

    Natural occurrence of crown gall on conifers has been reported on *Cupressus arizonica, Libocedrus decurrens, Araucaria bidwillii,* and *Araucaria excelsa.* The results of artificial inoculations on species of *Cupressaceae* with *Bacterium* (*Agrobacterium*) *tumefaciens* are reported in this paper. The cultures of the organism used in the inoculations were isolated from *Prunus persica, Libocedrus decurrens,* and *Salix* spp.

15. Spiers, A.G. 1980. Biological control of *Agrobacterium* species on *Salix.* New Zealand Journal of Agricultural Research 23(1):139-142.

    Control of crown gall disease, caused by *Agrobacterium tumefaciens,* by *A. radiobacter* var. *radiobacter* str. 84 was evaluated on cuttings of *Salix matsudana* and *S. purpurea* cv. both in pot and field trials. Control was complete in pot trials with str. 84 levels of >106 cells/ml. Control was not complete in field trials because of the presence of pathogens resistant to bacteriocin 84.

Damping-Off

(*Fusarium* spp., *Pythium* spp., others)

The bibliography includes 47 references on damping-off; 27 of these discuss damping-off in Pacific Northwest nurseries. The majority of articles deal with Douglas-fir or conifers in general; other hosts include lodgepole pine, ponderosa pine, sugar pine, spruce and true fir. We found that seven references cover various aspects of the biology of damping-off fungi (1, 4, 5, 14, 17, 33, 36), four references deal with pest detection and impact on the host (2, 3, 23, 24) and the remainder with management of the disease. Chemical control trials on seed, seedlings or soil are report in 15 references. Several articles report results from trials using both chemical and cultural methods (9, 10, 11, 19, 26). Two references were found (13, 20) reporting use of biological control. One

paper discusses reinfestation of sterilized nursery beds by both pathogenic and beneficial fungi (43). General management strategies for damping-off are discussed in eight references (7, 16, 31, 34, 35, 38, 41, 44).

1. Bloomberg, W.J. 1971. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 61:467-470.

   Isolates of *Fusarium oxysporum* were obtained from roots of Douglas-fir seedlings without disease symptoms or with one of the following diseases: postemergence damping-off, root rot, or corky root. Isolates varied in infectivity, pathogenicity, types of disease they caused, and their ability to kill seedlings of different ages. Pathogenicity was greatest in seedlings growing in nutrient agar, intermediate in sterile nursery soil, and lacking in sterile peat-sand mixture.

2. Bloomberg, W.J. 1976. Simulation of Douglas-fir seedling root growth, damping-off and root rot. Canadian Forestry Service, Pacific Forest Research Centre, Report BC-X-127.

   A FORTRAN computer model was constructed for *Pseudotsuga menziesii* in a nursery in British Columbia. The model is an integrated system with four components: seedling attributes; environmental factors; pathogen (*Fusarium oxysporum*) behavior; and the disease process. A simplified flow chart and modelling procedures are given. Model predictions in two seasons amounted to 72 to 121 percent of actual nursery results. Applications include determination of optimum timing for root pruning, fertilization, and disease prediction.

3. Bloomberg, W.J. 1979. A model of damping-off and root rot of Douglas-fir seedlings caused by *Fusarium* oxysporum. Phytopathology 69:74-81.

   The mathematical relationships required to construct a model of damping-off and root rot of Douglas-fir seedlings caused by *Fusarium* oxysporum were derived from the literature, unpublished data, and experiments. A time and space frame of 180 days from sowing, in plots 0.1 to 0.2 m^2 x 20 cm deep containing up to 100 seedlings, was selected. Simplifications and as-

sumptions in the model included use of temperature as the main environmental factor, subdivision of time into 5-day periods and space into 2 cm intervals, with one vertical and one horizontal dimension, and natural variation based on pseudo-random selections from normal distributions. Using chi-squared goodness-of-fit, model predictions of germination, root growth, and root rot mortality were not significantly different from nursery results in 4 years. Predictions of number of seedlings and seedling roots infected ranged from 72 to 120 percent of nursery results.

4. Bloomberg, W.J. 1981. Disease caused by *Fusarium* in forest nurseries. IN: *Fusarium*: diseases, biology, and taxonomy, p.178-187. Edited by P.E. Nelson, T.A. Toussoun, R.J. Cook. Pennsylvania State University Press.

   Reviews disease types, distribution, pathogenicity, races and strains, damage, environmental factors, and control.

5. Bloomberg, W.J. and W. Lock. 1972. Strain differences in *Fusarium oxysporum* causing diseases of Douglas-fir seedlings. Phytopathology 62:481-485.

   Axenically grown Douglas-fir seedlings were inoculated with *Fusarium oxysporum* isolates obtained in a nursery from roots of healthy Douglas-fir seedlings or from roots of seedlings infected with preemergence damping-off, postemergence damping-off, root rot, or corky root. All isolates killed all seedlings, but there were significant differences among isolates in the chronological pattern of mortality they produced. In seedlings growing in controlled environments in naturally infested soil, there was not significant association between any one disease caused by *F. oxysporum* and another. In nurseries, there were no significant correlations between the levels of one disease and another.

6. Buckland, D.C. 1942. Further experiments of the control of damping-off in Douglas-fir using commercial peat as the planting

medium. Department of Agriculture (Canada), Forest Biology Division, Unpublished Report.

Following a laboratory experiment on the control of damping-off using commercial peat as a planting medium, it was proposed to carry out further experimentation more nearly approaching forest nursery conditions. Results of the experiment indicated that the peat method gave satisfactory control of preemergence and postemergence damping-off, and possibly some control of top rot of seedlings. The top growth of seedlings was greater than those grown in untreated soil, but the root system was smaller and inadequate.

7. Carlson, L.W. 1972. Forest tree nursery disease control. IN: Western Forest Nursery Council and Intermountain Forest Nurserymen's Association, Proceedings of Joint Meeting, 1972, p.111-114. Edited by H.W. Anderson, J.A. Bryan, R.P. Eide. Held August 8-10, 1972, Olympia, Washington.

   Reviews chemical and cultural practices for control of the major disease problems: damping-off, gray mold, *Lophodermium*, and storage molds.

8. Conway, K.E. 1987. The potential of soil solarization in nurseries to control soil-borne diseases. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-151, p.27-29. Meeting the challenge of the Nineties: Proceedings, Intermountain Forest Nursery Association, edited by T.D. Landis. Held August 10-14, 1987, Oklahoma City, Oklahoma.

   Use of clear polyethylene sheeting to heat soil, through the technique called soil solarization, is being evaluated as a method to control soil-borne pathogens at the Oklahoma Division of Forestry Nursery. Studies are directed at the effects of solarization on population densities of *Pythium* species, *Macrophomina phaseolina*, and *Sclerotium rolfsii*. Soil temperatures under polyethylene sheeting during August to September reached maxima of 10 to 12 degrees C greater than bare ground controls.

9. Cooley, S.J. 1982. Soil solarization in a forest nursery for the control of nursery pests. USDA Forest Service, Pacific Northwest Region, Forest Pest Management.

A new soil treatment, solarization, was compared to soil fumigation and no treatment in an eastern Oregon conifer nursery. Seedling survival, weed reduction, and populations of soil fungi and nematodes were evaluated in all treatments. Fumigation resulted in superior survival and stand of ponderosa pine seedlings during the first 10 weeks after emergence. Seedling survival in solarized areas was similar to that in check areas. Weed control was best in fumigated and poorest in check plots. Both fumigation and solarization resulted in lowered populations of *Fusarium* spp. and several groups of nematodes when sampled immediately after treatment. Soil temperatures at depths of 5, 15, an 30 cm were at least 10 degrees higher during solarization than temperatures in non-solarized soil. Operational use of solarization cannot be recommended until further solarization trials show levels of pest reduction and seedling survival similar to those seen with fumigation. The causes for poor performance in solarized plots are discussed.

10. Cooley, S.J. 1985. Evaluation of solarization and fumigation at the J. Herbert Stone Nursery. USDA Forest Service, Pacific Northwest Region.

Fumigation and solarization were compared at the J. Herbert Stone Forest Nursery in southwest Oregon for disease and weed control. Fumigation resulted in significantly reduced levels of weeds and disease. Solarization, while reducing the number of weeds, did not decrease disease severity. Possible reasons for poor disease control with solarization are discussed.

11. Cooley, S.J. 1985. Solarization in two Pacific Northwest forest nurseries. IN: USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.45-48. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

12. Cooley, S.J. and B. Kelpsas. 1988. Comparison of 3 soil fumigants in a bareroot conifer nursery. Tree Planters Notes (in press).

Nursery soil was treated with dazomet (Basamid®), metam sodium (Soil Prep®), methyl bromide chloropicrin (Dowfume MC-33®) or left untreated. All three chemical treatments resulted in reduced levels of pathogenic fungi in the soil and improved ponderosa pine seedling survival and stand density. Seedling growth was the same regardless of treatment or no treatment in the first growing season. Some growth differences were seen after the second growing season. Height and caliper variation was least with the dazomet treatment. Utilization of these chemicals in conifer nurseries is discussed.

13. Danielson, R.M. and C.B. Davey. 1969. Microbial recolonization of a fumigated nursery soil. Forest Science 15(4):368.

Soil fumigation with methyl bromide resulted in the dominance among the fungi of *Trichoderma* species and *Penicillium piscarium* in both the soil and rhizosphere. The inoculum source was a pine needle mulch applied following fumigation. Application of a microbiologically different mulch resulted in a different fungal population which was still detectable after 4 months. The fungal population in the subsurface soil remained at a very low level throughout the study period of 7 months. The bacteria responded immediately and strongly to fumigation. Numbers in the subsurface soil subjected to high levels of methyl bromide exceeded the numbers in the controls by 10 to 20 times immediately after removal of the fumigation covers. Their populations fell sharply but remained above the control populations throughout the study. The fungal species isolated from the rhizosphere were the same as those isolated from the soil, but 7 of the 19 species isolated from surface-sterilized roots were not recorded from either the soil or rhizosphere. Larger

numbers of fungi in genera known to include plant pathogens were isolated from the surface-sterilized root tips of seedlings grown in nonfumigated soil than from fumigated soil. Clamp-bearing basidiomycetes were isolated from roots from all treatments. Histological and morphological examinations of roots indicated that fumigation delayed mycorrhiza formation for several weeks and altered the fungal symbionts involved.

14. Graham, J.H. and R.G. Linderman. 1983. Pathogenic seedborne *Fusarium oxysporum* from Douglas-fir. Plant Disease 67(3): 323-325.

    The fungus was isolated from 1 to 5 percent of the seed from 2 of 6 *Pseudotsuga menziesii* sources examined. Isolates were recovered from both washed and H_2O_2-treated seed, and from the roots of diseased seedlings where infection occurred on random individual seedlings (some in growth chambers), indicating it to be seed-borne. Soaking the seed in spore suspensions of seed or root isolates caused considerable preemergence damping-off or seed rotting compared with uninoculated controls. Root isolates caused more postemergence damping-off. Some preemergence and postemergence damping-off occurred in uninoculated controls from which *F. oxysporum* was recovered, due to either seed-borne inoculum or cross-contamination. Sporulation was observed on above-ground infected stems or cotyledons and seed coats and on the medium surface; spores could easily have been air-borne or water-splashed to other seedlings. Implications of the results in relation to the seed-borne contamination of fumigated nursery beds or into container nurseries with subsequent spread are discussed.

15. Hadfield, J.S. and R.D. Harvey, Jr. 1974. Field evaluation of Arasan 75® and Benlate 50W® as a seed protectant for Douglas-fir at the Wind River Nursery, 1974. USDA Forest Service, Pacific Northwest Region.

    After controlled environmental chamber tests in 1973, Arasan 75® and Benlate 50W® were selected to be evaluated in the field for their fungicidal effectiveness as seed treatments in preventing damping-off in Douglas-fir seedlings. Initial soil samples contained low populations of *Pythium* and *Fusarium* spp. Final

data did not reveal any significant difference between survival or emergence rates of treated or non-treated seeds. The lack of significant differences might be attributed to the low levels of pathogenic fungi found in the areas chosen for the evaluation.

16. Hartley, C. 1921. Damping-off in forest nurseries. USDA Bulletin 934.

    Describes damping-off of conifers and the causal fungi involved: *Corticium vagum, Fusarium* spp., *Pythium debaryanum, Rheosporangium aphanidermatus, Phytophthora* spp. and miscellaneous Phycomycetes. Discusses the role of damping-off fungi in causing root rot and late damping-off, and effect of environment, sowing density, moisture, temperature, soil properties, and other soil organisms on damping-off.

17. Hildebrand, D.M. 1985. Pathogenicity of *Fusarium* spp. to lodgepole pine. USDA Forest Service, Rocky Mountain Region, Forest Pest Management, Biological Evaluation R2-85-8.

    In order to determine which *Fusarium* species isolated from Colorado and Nebraska nursery soils and seedling were pathogenic to conifer seedlings, pathogenicity tests using lodgepole pine seed and seedlings were conducted. Twelve isolates frequently observed on medium selective for *Fusarium* spp. and assumed to be *Fusarium* spp. were used for in these tests. The *Fusarium* isolates were ranked according to the incidence of disease in lodgepole pine.

18. Hildebrand, D.M. 1985. Soil solar heating for control of damping-off fungi and weeds at the Colorado State Forest Service Nursery. Tree Planters' Notes 36(1):28-34.

    Sample plots were covered with 2-mil clear polyethylene for solar heating in July 1982 and removed after 55 days. Soil samples were collected from treated and untreated plots in June, August, and the following April. There were significant reductions in damping-off (*Pythium* spp. - reduced 60 percent on average and *Fusarium* spp. - reduced 74 percent). Germination of weed seeds from soil samples was significantly reduced, and weed cover was reduced by 97 percent on solar plots.

19. Hildebrand, D.M. 1985. Soil solar heating for reduction in populations of *Pythium*, *Fusarium*, nematodes, and weeds at the U.S. Forest Service Bessey Tree Nursery, Halsey, Nebraska. USDA Forest Service, Rocky Mountain Region, Technical Report R2-34.

Three plots were covered with 0.02 mm clear polyethylene tarp for solar heating for 8 weeks (June 21 to August 17) in summer 1983, and three plots were left fallow as checks. In spring 1984, three plots were fumigated with methyl bromide/chloropicrin prior to planting all plots with lodgepole pine seed. Soil samples were taken before and after soil treatments. Populations of *Pythium* spp. were significantly reduced by solar heating, but returned to high levels by spring, probably due to the effects of the sudangrass winter cover crop. Fumigation was less effective than solar heating in reducing populations of *Pythium* spp. in samples taken immediately after treatment. Reductions in populations of *Fusarium* spp. by solar heating were not statistically significant, and in samples taken immediately after treatment, reductions due to fumigation were similar to those due to solar heating. Weed populations were significantly reduced by solar heating, but returned to pre-treatment levels by the following spring. In samples taken immediately after treatment, solar heating was as effective as fumigation for weed control. No significant effects on lodgepole pine seedling survival resulted from any of the treatments. The winter cover crop grew more lush and darker green in solar plot locations than in the surrounding check area.

20. Hocking, D. and F.D. Cook. 1972. Myxobacteria exert partial control of damping-off and root disease in container-grown tree seedlings. Canadian Journal of Microbiology 18:1557-1560.

Many tree seedlings for reforestation are now being produced in small, discreet containers. On these seedlings, losses and stunting from root pathogens occur widely and unpredictably. Some myxobacteria of the group Cytophaga which produce powerful extracellular proteolytic and chitinolytic enzymes were introduced into fumigated or non-fumigated peat before or after sowing seeds of four species of conifer. They actively colonized the rhizosphere of the developing seedlings without affecting seedling development. In subsequent inoculation

tests with pathogenic fungi, there was significantly less mortality, chlorosis, and stunting than in checks without myxobacteria.

21. Jackson, L.W.R. 1940. Effects of H-ion and Al-ion concentrations on damping-off of conifers and certain causative fungi. Phytopathology 30:563-579.

    The amount of damping-off of ponderosa pine and Douglas-fir grown in liquid cultures, caused by *Pythium* and *Rhizoctonia* isolates, was lowest at pH 2.5 and 3.5, increased to maxima at 6.5 or less often 5.5, and then decreased at 6.5 or 7.5. Concentrations of aluminum sulphate showed little effect on damping-off in sand cultures at pH 3.5, and no effect at pH 6.5. These results suggest that the value of aluminum sulphate in the control of damping-off is due mainly to its low pH and not to aluminum as such.

22. James, R.L. 1984. Evaluation of fungicides to control root disease at the Champion Timberlands Nursery, Plains, Montana. USDA Forest Service, Northern Region, Forest Pest Management Report 84-9.

    Metalaxyl, Banrot®, captan, and benomyl were evaluated to reduce mortality of lodgepole pine, ponderosa pine, and Douglas-fir seedlings due to damping-off and root disease at the Champion Timberlands Nursery. Fungicides were applied as drenches before sowing and after seedling emergence. Seedling mortality and soil populations of *Fusarium* and *Pythium* were measured. Metalaxyl was the most effective fungicide in improving seedling survival. All fungicides initially reduced population levels of *Fusarium* and *Pythium* in the soil; however, levels increased in presence of susceptible conifer seedlings throughout the first growing season. Soil fungicides should only be used if the need to control damping-off and root disease has been clearly demonstrated and other more effective measures cannot be used.

23. James, R.L. 1984. Fungi colonizing Douglas-fir seed at the Champion Timberlands Nursery, Plains, Montana. USDA Forest Service, Northern Region, Forest Pest Management, Report 84-13.

Seed-borne pathogens may cause important losses to conifer seedlings in nurseries, particularly if infected seeds are sown in containers or recently fumigated seedbeds. Growers at the Champion Timberlands Nursery were concerned about relative rates of *Fusarium* contamination of *Pseudotsuga menziesii* seed because of recurring problems with early seedling losses. Therefore, tests were conducted to provide information on contamination rates. Frequency of contamination by *Fusarium* was slightly higher than previous assays of Douglas-fir seed. Levels of contamination may be related to seed sources or seed handling practices.

24. Johnson, D.W. 1975. The major causes of loss of seeds sown in 1972 at the Wind River Nursery, Carson, Washington. Tree Planters' Notes 26(3):14-15, 28.

Analyzes in detail the germination, survival, and growth during 1972-73 of seedlings of 13 coniferous seedlings raised from sowing in spring 1972 at this long-established nursery, which is an important source of softwood planting stock (80 percent Douglas-fir) but has proved susceptible to serious recurrent losses. Low winter temperatures, leading to frost-heaving, were the main cause of the plant losses recorded; other factors included damping-off and root rot. Preventive measures are discussed, and further research on the stratification of seed of *Abies* species is recommended.

25. Johnson D.W. and R.D. Harvey, Jr. 1975. Seed-protectant fungicides for control of Douglas-fir and ponderosa pine seedling root rots. Tree Planters' Notes 26(2):3-5.

Reports results of laboratory trials with seeds of *Pseudotsuga menziesii* and *Pinus ponderosa* sown in soils from two nurseries in Washington and Oregon infected with species of *Pythium*

and *Fusarium*. Treatment of the seeds with thiram, fenaminosulf or Preseed® gave some protection against early damping-off, but no protection against later root rot. Benomyl and captan gave little or no protection.

26. Johnson, D.W. and B. Zak. 1977. Effects of soil treatments on fungal populations and ponderosa pine seedling survival in an Oregon nursery. Plant Disease Reporter 61(1):43-47.

    Soil fumigation, soil acidification, and the addition of organic matter were evaluated for effectiveness in reducing losses of ponderosa pine seedlings to *Pythium* and *Fusarium* root rots in an Oregon nursery. Soil fumigation and addition of organic matter provided greater disease control than either soil fumigation or organic matter alone. Soil acidification with sulfur did not control the disease or reduce populations of pathogenic fungi.

27. Kliejunas, J. 1985. Effect of selected chemicals on mold development during conifer seed stratification and on subsequent germination. USDA Forest Service, Pacific Southwest Region, Forest Pest Management, Report 85-35.

    A study to determine the need for a pre-stratification treatment of conifer seed with Captan® to prevent mold development was conducted at the L.A. Moran Reforestation Center and at the Humboldt Nursery. Effectiveness of alternative treatments were also evaluated. Compared to no treatment, Captan 50W®-treated and Captan 42S® (thiram)-treated seeds were visually cleaner and no reduction in germination occurred. However, the molds that did develop on untreated seeds had no apparent effect on germination. Bleach dip or bleach soak treatments did not reduce mold development and generally reduced germination compared to no treatment. The use of non-chemical treatments to reduce mold development, including washing the seeds with water, decreasing surface moisture content after soaking, and increasing aeration during stratification, are discussed.

28. Lock, W., J.R. Sutherland and L.J. Sluggett. 1975. Fungicide treatment of seeds for damping-off control in British Columbia forest nurseries. Tree Planters' Notes 26(3):16-18, 28.

Describes field trials to test the value of eight fungicides in preventing preemergence and postemergence damping-off in seeds and seedlings of *Pseudotsuga menziesii, Picea sitchensis, P. glauca,* and *Pinus contorta.* Fungicides were applied to the seeds by different methods and the seeds were sown in 1971, 1972 and 1973. Results show that none of the fungicides tested gave a consistent increase in plant survival; they could, however, be used to prevent severe losses in years when damping-off is endemic. Benlate®, although ineffective against *Pythium* and *Phytophthora,* is recommended because it is less phytotoxic than the more commonly used captan. Since soaking seeds in fungicide proved ineffective, the problem of achieving uniform seedling densities with pelleted seeds remains.

29. McDonald, S.E., J.A. Isaacson, B.E. Fisher and R.M. Raymond. 1973. Post-planting fungicide application to reduce losses to damping-off fungi may be detrimental. Tree Planters' Notes 24(2):14-15.

Busan® (3 lb/120 gal water per acre) and Terraclor® (10 lb/100 gal water per acre) were applied in June immediately after sowing stratified seed of *Pseudotsuga menziesii* var. *glauca,* with two control plots, in a nursery in Idaho. Total seedling counts, mortality counts and percent mortalities at intervals from July to October showed that the fungicides had an adverse effect on germination and seedling survival in July, but were beneficial in reducing the normal surge of mortality in late summer. In view of the overall adverse effect of the fungicides, they have not been used on a field scale.

30. Peterson, G.W. 1970. Seed-protectant chemicals affect germination of ponderosa pine seed. Tree Planters' Notes 21(4):25-29.

Seed-protectant chemicals were bound to ponderosa pine seed with methyl cellulose or latex. Results show that the amount of fungicide must be closely controlled to avoid reductions in the amount and speed of germination. Further, high temperatures may cause significant reductions in amount and speed of germination even when seeds are treated with moderate amounts of fungicide.

31. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including damping-off.

32. Riffle, J.W. and H.W. Springfield. 1968. Hydrogen peroxide increases germination and reduces microflora on seed of several southwestern woody species. Forest Science 14(1):96-101.

Washing seeds of *Pinus ponderosa, P. edulis, Juniperus monosperma, Atriplex canescens, Cercocarpus montanus,* and *Cowania mexicana* in water for 48 hours, followed by a half hour soaking 30 percent hydrogen peroxide, increased the germination of all species except *A. canescens*. Soaking in water, followed by the peroxide treatment, improved the seed germination of four of the species. Soaking or washing without the peroxide treatment proved less effective; in fact, most water treatments were detrimental to *A. canescens* and *C. montanus* seeds. The peroxide treatment effectively reduced seed-borne microflora, but induced some abnormal seedling development of the three shrub species.

33. Salisbury, P.J. 1952. The effect of temperature and hydrogen-ion concentration on growth of certain cultures of *Fusarium oxysporum* isolated from Douglas-fir seedlings. Dominion Department of Agriculture (Canada), Mimeo Report.

Fusarium oxysporum forma *pini* and *Fusarium redolens* were grown in vitro at different pH's. They behaved in vitro like high temperature fungi, cardinal temperatures being 10, 25 and 30 degrees C. They were tolerant to a wide range of hydrogen-ion concentrations; limits for growth in vitro were approximately pH 2.1 and pH 9.1.

34. Salisbury, P.J. 1954. A review of damping-off of Douglas-fir seedlings in British Columbia. Forestry Chronicle 30:407-410.

Except in new nurseries, damping-off in British Columbia forest nurseries has remained below serious levels. Modification of nursery practices has served to reduce losses. The use of a suitable, sandy cover soil has been effective. Lowered fertility of the soil, though a problem in itself, appears to decrease incidence of damping-off. The acidity of the soil in coast nurseries may have afforded some natural control of the disease. From investigations on the control of damping-off, there appears to be promise in the use of peat as a planting medium for stratified seed, and, based on experiments with unstratified seed, in the application of fungicides to cover soil. In view of the present low degree of the disease, there would appear to be an opportunity for research directed to the biology and control of fungi known to be capable of causing sudden outbreaks, without the urgent need of finding immediately effective control measures.

35. Schmitthenner, A.F. 1970. Significance of populations of *Pythium* and *Phytophthora* in soil. IN: Root disease and soil-borne pathogens, p.25-27, edited by T.A. Toussoun, R.V. Bega, P.E. Nelson. University of California Press.

    High soil moisture is necessary for development of root and seed rots caused by *Pythium* and *Phytophthora*. The primary effect of high soil moisture is decreased oxygen. Both *Pythium* and *Phytophthora* grow well in low oxygen that may damage higher plants. *Pythium* and *Phytophthora* might be controlled more easily by manipulating soil moisture, where this is possible, than by attempting to eliminate the pathogens.

36. Shea, K.R. and J.H. Rediske. 1961. Pathological aspects of germination and survival of Douglas-fir in controlled environment. Weyerhaeuser Company, Forestry Research Center, Forestry Research Note 41.

    Losses attributable to damping-off are variable, differing in degree from year to year. Environmental factors undoubtedly play an important role in severity. To develop suitable measures for reducing these losses, it is essential to reproduce damping-off at will under controlled conditions. The purpose of the present study was to investigate the effect of soil temperature on the pathology of Douglas-fir seed and seedlings in a controlled environment.

37. Smith, R.S., Jr. and R.V. Bega. 1966. Root disease control by fumigation in forest nurseries. Plant Disease Reporter 50(4):245-248.

Seed-borne diseases are a major problem in the forest nurseries of California. Losses of 50 percent have occurred in past years. Control tests were begun at one nursery using three fungicides and four fumigants. All treatments gave some control, but the fumigants gave better control than the fungicides. Mortality in check plots averaged 50 percent; in fumigated plots, 7 to 11 percent. Seedlings from fumigated plots were larger and healthier than those from check plots.

38. Sutherland, J.R. and R.L. Anderson. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. IN: North American Forest Tree Nursery Soils Workshop, Proceedings, p.182-190. Held July 28-August 1, 1980.

Soil conditions play a major role in preventing or causing devastating losses from many nursery disease and insect problems. This paper reviews the relationships between several soil factors, cultural practices, and certain disease and insect problems.

39. Sutherland, J.R. and W. Lock. 1977. Fungicide-drenches ineffective against damping-off of Sitka and white spruces. Environment Canada, Forestry Service, Bi-monthly Research Notes 33(1):6-7.

Applications of captan, benomyl and carboxin at various rates and at various times after seed sowing provided no protection against damping-off of Sitka spruce (*Picea sitchensis*) and white spruce (*P. glauca*) in forest nurseries.

40. Sutherland, J.R., W. Lock and L.J. Sluggett. 1975. Damping-off in British Columbia forest nurseries: control trials with fungicides applied to different quality seeds. Canadian Forestry Service, Pacific Forest Research Centre, Report BC-X-125.

Describes nursery and growth-room experiments at Koksilah and Surrey, B.C., with seed of high, intermediate, and poor quality of *Pseudotsuga menziesii*, *Picea sitchensis* and *P. glauca*, to determine the phytotoxicity and effectiveness in controlling

damping-off with captan, Benlate®, Benlate T®, MBC-P®, and talc, applied to the seed after stratification. Results showed that none of the treatments had any effects of practical importance on the percent or rate of emergence, early or late incidence of damping-off, or shoot growth, with any of the species or seed qualities tested. The effects of seed quality per sé were readily discernible at both nurseries for all species. At Surrey, *P. menziesii* shoot growth decreased, and early incidence of damping-off increased, with decreasing seed quality. In the growth room, germination capacity and speed of germination of treated seeds were improved by fungicides, but these effects were not evident in the field. Most germination failure in vitro was attributable to seed decay, but the percent of decayed seeds, based on the number of ungerminated seeds, was seldom reduced by seed treatment.

41. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

    Reviews hosts, damage, life history and control of various nursery diseases, including damping-off.

42. Thies, W.G., P.W. Owston and D.C. Hansen. 1980. Effects of four fungicides on survival and growth of containerized Douglas-fir seedlings: performance. Canadian Journal of Forestry Research 10:423-425.

    Several disease control strategies were tested on Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings grown in a greenhouse-shadehouse facility in western Oregon. Potting mixture was exposed to two pasteurization treatments combined factorially with four fungicides (benomyl, captan, fenaminosulf, and ethazole) and three application schedules (pregermination drench, postgermination drenches, and a combination of pregermination and postgermination drenches). Both pasteurization of the potting mixture and applications of fenaminosulf caused statistically phytotoxic effects.

43. Vaartaja, O. 1967. Reinfestation of sterilized nursery seedbeds by fungi. Canadian Journal of Microbiology. 13:771-776.

Incidences of soil fungi were recorded for 1 cm^3 volumes of untreated and fumigated nursery soils using new selective isolation media. In July, 10 months after application of Trizone® at 1 lb/100 ft^2, there were many viable *Pythium* propagules in the treated surface soil (11/cm^3) but significantly fewer than in nonfumigated soil (29/cm^3). Studies with baits showed that *Rhizoctonia* and *Fusarium* spp. were also present in both soils. The total number of fungi in fumigated soil (11,000) was lower than in nonfumigated soil (30,000). *Trichoderma* propagules were very common and significantly more so in fumigated (1,120) than in nonfumigated soil. The same held for bacteria (10 million vs. 7 million). Reinfestation with four potentially pathogenic genera of fungi was found to take place by means of splashing rain and irrigation water, dust, and soil carried by workers.

44. Vaartaja, O. 1964. Chemical treatments of seedbeds to control nursery diseases. Botanical Review 30(1):1-91.

Reviews world literature on this subject under the main heads: seed treatments; soil acidifying; soil fumigation; soil treatments with (a) mercury fungicides, (b) other metallic fungicides, (c) organic fungi-toxicants; foliage treatments; summary of empirical research; systemic fungitoxicants and chemotherapeutants; antibiotics; nematocides; and factors affecting chemical control in soil.

45. Vaartaja, O., J. Wilner, W. Cram, P. Salisbury, A. Crookshanks and G. Morgan. 1964. Fungicide trials to control damping-off of conifers. Plant Disease Reporter 48(1):12-15.

Presents results of experiments with various fungicides and mixtures of fungicides. Results were not consistent, but some control was obtained by repeated applications of captan, Dexon®, Dyrene®, thiram or zineb.

46. van den Driessche, R. 1963. Nursery experiments with Douglas-fir. Commonwealth Forestry Review 42(3):242-254.

Seven experiments with Douglas-fir at three coastal British Columbia nurseries are described. Seedling size was increased by autumn sowing, by very early spring sowing, or by reducing seed bed density. Only seedlings sown as early as March responded to nitrogen fertilizer applied in July. Nitrogen at 40 lb/acre was the most suitable rate of application for such seedlings. During the first year, application of nitrogen ferilizer to seedlings sown much later than March gave little response and stimulated damping-off. Heavy nitrogen fertilization during the second year gave good response at two nurseries. The growth responses to calcium and magnesium were apparently due to decreased seed bed density caused by these two fertilizers.

47. Wall, R.E. and J.R. Cormier. 1976. Fungicidal drench trials for the control of damping-off in conifer seed beds. Canadian Forestry Service, Maritime Forest Research Centre, Information Report M-X-61.

Seventeen fungicidal formulations, plus several combinations containing two or more active ingredients, were tested for control of damping-off under field, greenhouse and laboratory conditions. Many of the single chemicals had a narrow spectrum of activity against the damping-off fungi and consequently failed to control seedling mortality where several pathogenic fungi were present. Other were phytotoxic, thereby causing seedling mortality to the same extent as damping-off. None of the single compounds were consistently beneficial under the rigorous conditions of these tests. Combinations of systemic benzimidazole with ethazole or chloroneb were promising, significantly increasing seedling survival.

Dothistroma Needle Blight

(*Dothistroma pini*)

There are 14 references listed in our bibliography for Dothistroma needle blight. Much of the work summarized here has been on ponderosa, lodgepole, and Austrian pines in the Great Plains States. There are only two papers dealing with the disease specifically in the Pacific Northwest (2, 11). Other than three general references on the biology and control of *Dothistroma* in nurseries (7, 9, 12), the rest of the citations

deal with the disease in plantations. Six references are listed which focus on the biology of *Dothistroma* (1, 6, 8, 10, 11, 13), one on detection of the disease (2), and the remainder on some aspect of management. Two papers look at chemical control (3, 4); one looks at general management strategies (7); and four are general references which cover both biology and control (5, 9, 12, 14).

1. Eldridge, R.H. and H. Dowden. 1980. Susceptibility of five provenances of ponderosa pine to *Dothistroma* needle blight. Plant Disease 64(4):400-401.

   An 11-year-old provenance trial of *Pinus ponderosa* was assessed for differences in susceptibility to *Dothistroma septospora*. Marked differences in percentage of needles infected, number of lesions per needle, and percentage of dead needle tissue indicated two groups. When grown in an inland area with little maritime influence, provenances from inland regions were less susceptible to *Dothistroma* than were trees originating in humid coastal climates.

2. Parker, A.K. and D.G. Collis. 1966. Dothistroma needle blight of pines in British Columbia. Forestry Chronicle 42:160-161.

   During 1963, a foliage disease seriously affected several species of exotic pines on Vancouver Island. In the spring of 1964, the organism responsible was identified as *Dothistroma pini*. Subsequent random surveys have shown the disease to be widespread throughout British Columbia on three native pines (*Pinus contorta, P. monticola, P. ponderosa*), and present on six species of exotic pines.

3. Peterson, G.W. 1965. Dothistroma needle blight of Austrian pine: infection and control. Plant Disease Reporter 49(2):124-126.

   Presents the results of tests made in 1963 to compare the effectiveness of four fungicides (Bordeaux mixture, zineb, captan, and Puratized® agricultural spray) in controlling *Dothistroma pini* in a 30-year-old *Pinus nigra* plantation. Best results were obtained with Bordeaux mixture, but since *D. pini* can infect previous seasons' needles as well as newly developing ones (not previously reported), further studies are needed to determine the most effective number and timing of applications.

4. Peterson, G.W. 1967. Dothistroma needle blight of Austrian and ponderosa pines: epidemiology and control. Phytopathology 57:437-441.

A study of *Dothistroma pini* in 30- to 32-year-old plantations in Nebraska. Symptoms appeared and stromata began to develop in the autumn of the infection year. Conidia developed in early spring and were discharged in later spring and summer during periods of rain. They germinated at 12 to 28 degrees C; first infection occurred early in the growing season, especially during humid and moderately cool weather. In most trees, current needles, initially resistant, became susceptible in mid-summer, but in some they remained resistant. General resistance varied greatly between individual trees. Scots pines in severely infected Austrian pine stands were also free from infection. Two properly timed applications of Bordeaux mixture gave good control. Other Cu fungicides (tribasic Cu sulphate, COCS®, TC-90®) were also effective, but COCS® was slightly phytotoxic. Puratized®, Actispray®, and Difolatan® were unsatisfactory.

5. Peterson, G.W. 1967. Dothistroma needle blight of pines in North America. IN: International Union of Forestry Research Organizations, 14th World Congress, 5:269-278.

Dothistroma pini has been found in 22 of 50 states in the United States and 3 provinces of Canada; it has not been reported in Mexico or Central America. This pathogen has been found on 20 pine species and hybrids in North America, but is found most frequently on *Pinus nigra* and *P. ponderosa*. Epidemiological research has provided the basis for excellent control of Dothistroma needle blight with two properly timed applications of Bordeaux mixture or other copper fungicides in plantations in the central United States.

6. Peterson, G.W. 1973. Infection of Austrian and ponderosa pines by *Dothistroma pini* in eastern Nebraska. Phytopathology 63:1060-1063.

The fungus *Dothistroma pini* has damaged pines in the mid-western United States for many years. Yearly differences in

weather result in considerable yearly variation in amount of infection by *D. pini*. Thus, adequate information for development of effective and economical control measures must be obtained over a number of years. This paper summarizes and interprets studies on epidemiology that have been underway since . Results provide a sound basis for determining when protective fungicides should be applied in eastern Nebraska.

7. Peterson, G.W. 1975. Dothistroma needle blight: a problem in production of landscape pines. American Nurseryman 141(12):11, 94-96.

Nurseries producing pines for landscapes are being confronted with a needle disease caused by the fungus *Dothistroma pini*. Twenty pine species and hybrids are known hosts and the fungus has been found in 23 states in the United States. Some nurseries have discontinued growing highly susceptible pines. However, research in Nebraska has shown that this disease can be controlled inexpensively. Pines heavily infected over the entire crown have been saved for sale by methods described in this article.

8. Peterson, G.W. 1981. Research in the United States on Dothistroma needle blight of pines. IN: Current research on conifer needle diseases, proceedings of IUFRO Working Party, edited by C.S. Millar. Held September 15-19, 1980, Sarajevo, Yugoslavia.

Reviews research on *Dothistroma pini* conducted in the United States, presenting information on geographic distribution and hosts infected, describing current research and results on genetics resistance to D. pini within *Pinus nigra* and *P. ponderosa*, and giving some suggestions for additional research.

9. Peterson, G.W. 1982. Dothistroma needle blight of pines. USDA Forest Service, Forest Insect and Disease Leaflet 143.

Dothistroma damages plantations of lodgepole and Monterey pines in California, Oregon, and Washington, as well as ponderosa pine in the Great Plains and eastern United States. The fungus has seldom been detected in young seedlings in nurseries, but experience with epidemics in isolated new plantings

indicates that trees infected in the nursery must have been responsible. Life cycle and control of the fungus are discussed.

10. Peterson, G.W. 1984. Resistance to *Dothistroma pini* within geographic seed sources on *Pinus ponderosa*. Phytopathology 74:956-960.

    In plantings of *Pinus ponderosa* established in 1968 in Nebraska, Oklahoma, and Missouri, seedlings from a total of 78 geographic seed sources were tested for resistance to *Dothistroma pini* which causes needle blight. There was high resistance to *D. pini* in seedlings from six of the sources. Trees from most of these sources were above plantation averages in height after 10 years of growth. Thus, there are a number of areas where seed can be collected for the production of seedlings that may be planted where *D. pini* is a threat.

11. Peterson, G.W. and G.M. Harvey. 1976. Dispersal of *Scirrhia (Dothistroma) pini* conidia and disease development in a shore pine plantation in western Oregon. Plant Disease Reporter 60(9):761-764.

    Information pertinent to the development of effective and economical controls for *Dothistroma pini* has been obtained in the Central United States but is lacking for the Western United States. This study on a *Pinus contorta* Christmas tree plantation was initiated to determine: 1) when and under what conditions conidia were dispersed, and 2) how disease development in the West differs from development in the Midwest. Conidia were dispersed and infection occurred earlier in western Oregon than in the Midwest; thus, the schedule of fungicide applications effective in the Midwest should be modified for control in Oregon.

12. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

    Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Dothistroma needle blight.

13. Peterson, G.W. and J.A. Walla. 1978. Development of *Dothistroma pini* upon and within needles of Austrian and ponderosa pines in eastern Nebraska. Phytopathology 68:1422-1430.

    Investigations of Dothistroma needle blight on ponderosa and Austrian pines in eastern Nebraska have led to the development of effective and economical controls for this disease in Christmas tree, shelterbelt, park, landscape and other plantings in the Great Plains and elsewhere in the United States. This article presents results of current investigations on the development of *Dothistroma pini* on and within needles of ponderosa and Austrian pines. This information was needed to understand infection and disease development.

14. Riffle, J.W. and G.W. Peterson. 1986. Diseases of trees in the Great Plains. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-129.

    Discusses hosts, distribution, symptoms and signs, disease cycle, damage, and control of a variety of diseases, including Dothistroma blight of pines, Sirococcus shoot blight, and western gall rust.

Fusarium Hypocotyl Rot

(*Fusarium oxysporum*)

We list 14 references on Fusarium hypocotyl rot. All work on this disease has been done on Douglas-fir in Oregon and Washington and on sugar pine in northern California (2, 3) from 1980 to 1988. There are six references (1, 3, 9, 10, 11, 13) describing some aspect of the biology of the disease. The remaining papers cover disease management; these deal with chemical treatment of seedlings (7) or soil (8), cultural treatment (14) or combination of the two (2, 4, 5, 6). One reference (12) discusses general management techniques for Fusarium hypocotyl rot.

1. Anonymous. 1985. Nursery pathology research project. Oregon State University, Forest Research Laboratory, Nursery Technology Cooperative Annual Report 1984-85, p.11-12.

After 2 years of detailed disease monitoring, some aspects of the top blight disease complex of Douglas-fir have been clarified. Pathogens involved include *Fusarium oxysporum* on hypocotyls, *Phoma eupyrena* and *Fusarium roseum* on the upper stem, and *P. eupyrena, F. roseum* and *Phoma pomorum* on the lower stem during the first year, and *Phomopsis* near the base of new growth in the second year. All fungi involved are soil inhabitants, spread by rain and soil movement; therefore, soil management will be a key part of any successful control.

2. Brownell, K. 1980. Sugar pine hypocotyl rot in California forest nurseries. Western International Forest Disease Workshop, Proceedings, 28:84-85.

During the past 5 years, a hypocotyl rot disease has caused excessive losses in sugar pine seedlings at the forest nurseries in Placerville and Magalia. Experiments by the author proved that the causal agent is *Fusarium oxysporum*. Fumigation and benomyl drenches both failed to give adequate control. Cultural control by altering planting date is being tested.

3. Brownell, K.H. and R.W. Schneider. 1983. Fusarium hypocotyl rot of sugar pine in California forest nurseries. Plant Disease 67(1):105-107.

A hypocotyl rot disease of sugar pine is described that caused severe losses in less than 3-month-old seedlings of *Pinus lambertiana, Abies concolor,* and *A. magnifica* in California forest nurseries. *Fusarium oxysporum* was found to be the causal organism. Greenhouse-grown seedlings developed resistance to infection by the third week after emergence, and roots were resistant at all ages. Hypocotyl rot strains were not pathogenic when tested against 14 agricultural hosts. Nine strains of *F. oxysporum* from agricultural hosts were not pathogenic when tested against *P. lambertiana*. Strains from Oregon ponderosa pine hypocotyl cankers were pathogenic on *P. lambertiana* hypocotyls.

4. Cooley, S.J. 1982. Soil solarization in a forest nursery for the control of nursery pests. USDA Forest Service, Pacific Northwest Region, Forest Pest Management.

A new soil treatment, solarization, was compared to soil fumigation and no treatment in an eastern Oregon conifer nursery. Seedling survival, weed reduction, and populations of soil fungi and nematodes were evaluated in all treatments. Fumigation resulted in superior survival and stand of ponderosa pine seedlings during the first 10 weeks after emergence. Seedling survival in solarized areas was similar to that in check areas. Weed control was best in fumigated and poorest in check plots. Both fumigation and solarization resulted in lowered populations of *Fusarium* spp. and several groups of nematodes when sampled immediately after treatment. Soil temperatures at depths of 5, 15, and 30 cm were at least 10 degrees higher during solarization than temperatures in nonsolarized soil. Operational use of solarization cannot be recommended until further solarization trials show levels of pest reduction and seedling survival similar to those seed with fumigation. The causes for poor performance in solarized plots are discussed.

5. Cooley, S.J. 1985. Evaluation of solarization and fumigation at the J. Herbert Stone Nursery. USDA Forest Service, Pacific Northwest Region.

Fumigation and solarization were compared at the J. Herbert Stone Forest Nursery in southwest Oregon for disease and weed control. Fumigation resulted in significantly reduced levels of weeds and disease. Solarization, while reducing the number of weeds, did not decrease disease severity. Possible reasons for poor disease control with solarization are discussed.

6. Cooley, S.J. 1985. Solarization in two Pacific Northwest forest nurseries. IN: USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.45-48. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

7. Cooley, S.J. and A. Kanaskie. 1986. Evaluation of seven fungicides to control canker diseases of bare-root Douglas-fir in Pacific Northwest nurseries. USDA Forest Service, Pacific Northwest Region, Report R6-86-14.

   The fungicides Benlate®, Captan®, Chipco 26019®, Daconil 2787®, Difolatan®, Mertect®, and Zyban® were applied periodically at five nurseries in Oregon and Washington for control of Douglas-fir canker diseases. Hypocotyl rot, resulting from ground-line infections by *Fusarium oxysporum*, was reduced by Benlate® at two nurseries; the other fungicides were less effective. Upper stem infections resulting in top mortality were caused primarily by *Phoma* spp. and *Fusarium* spp. and occurred in October and early November. In two nurseries which experience relatively high levels of upper stem canker, all fungicides significantly reduced cankering. Lower stem cankers, seen in spring and summer of the second year, were not controlled by fungicides if cankers were at groundline; good control was achieved with Daconil® and Difolatan® when cankers were higher on the stem and not covered with a soil collar. Cankers caused by *Botrytis* were prevalent in the summer and fall of the second year at one nursery; all fungicides gave effective control, although Daconil® and Difolatan® were superior.

8. Cooley, S.J. and B. Kelpsas. 1988. Comparison of 3 soil fumigants in a bareroot conifer nursery. Tree Planters Notes (in press).

   Nursery soil was treated with dazomet (Basamid®), metam sodium (Soil Prep®), methyl bromide chloropicrin (Dowfume MC-33®) or left untreated. All three chemical treatments resulted in reduced levels of pathogenic fungi in the soil and improved ponderosa pine seedling survival and stand density. Seedling growth was the same regardless of treatment or no treatment in the first growing season. Some growth differences

were seen after the second growing season. Height and caliper variation was least with the dazomet treatment. Utilization of these chemicals in conifer nurseries is discussed.

9. Hamm, P.B. and E.M. Hansen. 1987. Stem canker disease of Douglas-fir in nurseries. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.106-108. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

   Diseases that kill above ground portions of Douglas-fir, formerly called "top blight", are listed. Disease recognition, time of infection, infection site, and causal agents are described.

10. Hamm, P.B., E.M. Hansen and A.M. Kanaskie. 1985. Symptomology of the "top blight" diseases of Douglas-fir bare-root seedlings in nurseries in the Pacific Northwest. Phytopathology 75(11):1367.

    Top blight, an ill-defined syndrome, describes at least three distinct periods of mortality. In mid-summer, when seedlings are 3 months old, a hypocotyl rot occurs at or just above the soil line. Seedling tops quickly turn brown while roots are not discolored. *Fusarium oxysporum* is isolated. From September through November, cankers, centered on bark fissures, lateral or terminal shoots, or needle scars, appear between the midstem and seedling apex. *F. roseum* (Fr) and *Phoma eupyrena* (Pe) are recovered. A third type of symptom, December through May, is associated with soil collars built up by irrigation and splashing rain. Seedlings are girdled at or above the cotyledon scar, with top symptoms sometimes not evident until new growth suddenly wilts during the spring. Fr and Pe are most frequently isolated from diseased seedlings.

11. Hansen, E.M. and P.B. Hamm. 1988. Canker diseases of Douglas-fir seedlings in Oregon and Washington bareroot nurseries. Canadian Journal of Forestry Research (In Press).

Canker disease in northwestern forest nurseries have been referred to collectively as "top blight." To distinguish among the various symptoms and their associated fungi, we made systematic observations of, and isolations from, *Pseudotsuga menziesii* seedlings through two crop cycles in four northwestern nurseries, and suspect fungi were subjected to pathogenicity testing. Five diseases were distinguished. Hypocotyl rot, caused by *Fusarium oxysporum*, kills seedlings during their first growing season. Upper stem canker, caused by *Phoma eupyrena* and *Fusarium roseum*, girdles seedlings in mid-stem in the fall of their first year. Lower stem canker, also caused by *P. eupyrena* and *F. roseum*, kills seedlings in the winter or early spring of their second year and is associated with soil collars built up by splashing water. *Botrytis* and *Phomopsis* cankers occasionally kill new shoots during the second year. Not all diseases are damaging every year or in every nursery.

12. Kanaskie, A. 1987. Management of the top blight disease complex. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.115-121. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

    The "top blight disease complex" refers to five separate but related diseases affecting above-ground portions of bareroot Douglas-fir seedlings. Disease losses can be reduced by altering cultural practices or applying fungicides. The following paper provides practical approaches and techniques for reducing losses from top blight.

13. Morgan, P. 1983. Fusarium stem rot of Douglas-fir seedlings. Plant Disease 67(4):441-442.

    Stem rot of *Pseudotsuga menziesii* seedlings caused by *F. roseum* 'Avenaceum' and *F. roseum* 'Sambucinum' is reported from Oregon, both new host records. Infected seedlings were detected during winter months and showed chlorosis and wilting associated with stem lesions 1 to 15 mm from the root collar. Isolates of both fungi were pathogenic on 1-year-old *P. menziesii* seedlings. Symptoms on infected seedlings were similar for both pathogens.

14. Russell, K.W. 1987. Reducing Fusarium top blight in 1-0 Douglas-fir by irrigation scheduling. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.131-134. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

    Dry Pacific Northwest summer weather is when one phase of top blight caused by *Fusarium* spp. infects 1-0 forest nursery seedlings. Top blight appears when nurseries use short cycle cooling irrigation during hot weather. Infection is prevented by deep watering up to one inch at infrequent intervals.

Fusarium Root Rot

(*Fusarium oxysporum*)

We include 49 references on Fusarium root rot. The vast majority of these deal with work in the Pacific Northwest on Douglas-fir, ponderosa pine or sugar pine. Other hosts include lodgepole pine, Engelmann spruce, species of true fir and conifers in general. Seven papers cover some aspect of the biology of *F. oxysporum* (2, 4, 9, 13, 33, 42, 43); seven deal with detection and impact, including loss prediction through use of models (5, 6, 7, 12, 21, 26, 30); and the remaining 29 cover management strategies. Six are general papers or references discussing both biology and management of the disease (8, 27, 31, 37, 38, 39). The majority of management work has been with testing fungicides or fumigants (1, 10, 11, 15, 18, 20, 23, 24, 29, 41, 44, 46, 48) or looking at both chemical and cultural methods (14, 16, 17, 22, 25, 32, 47, 49). Five references were found for biological control strategies (19, 34, 35, 36, 40).

1. Bloomberg, W.J. 1965. The effect of chemical sterilization on the fungus population of soil in relation to root disease of Douglas-fir seedlings. Forestry Chronicle 41:182-187.

    Nursery beds were treated with methyl bromide, Mylone®, Vapam®, CIPC® and simazine before sowing with Douglas-fir seed. In beds treated by the first three chemicals, the incidence of seedling root disease was 15, 45 and 75 percent of that in the untreated bed. There was little or no reduction of disease in the simazine and CIPC®-treated beds. Counts of fungi in soil dilu-

tion plates showed that methyl bromide and Mylone® caused the greatest reduction in the total fungus population of the soil; the species was smaller in soil treated by these chemicals than in soil from other treatments. Vapam® caused a moderate reduction in the total population. All treatments reduced the proportion of *Fusarium oxysporum* in the soil, the fungus principally found to be associated with root disease; however, this proportion did not appear to be correlated with disease incidence.

2. Bloomberg, W.J. 1971. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 61:467-470.

Isolates of *Fusarium oxysporum* were obtained from roots of Douglas-fir seedlings without disease symptoms or with one of the following diseases: postemergence damping-off, root rot, or corky root. Isolates varied in infectivity, pathogenicity, types of disease they caused, and their ability to kill seedlings of different ages. Pathogenicity was greatest in seedlings growing in nutrient agar, intermediate in sterile nursery soil, and lacking in sterile peat-sand mixture.

3. Bloomberg, W.J. 1973. Fusarium root rot of Douglas-fir seedlings. Phytopathology 63(3):337-341.

The incidence of root rot caused by *Fusarium oxysporum* on seedlings of *Pseudotsuga menziesii* varied significantly among seedling provenances, sampling years (during a 4-year study period), nurseries, and seedbeds within nurseries. It was greater on the north side of shaded, enclosed beds than on the south side, and in spring-sown, open, unshaded beds than in autumn-sown, shaded, enclosed beds. It was not prevalent in seedlings greater than 30 days old that had been transplanted into infected soil. Disease incidence was greatly increased by temperatures greater than 23 degrees C for more than 6 hours per day during the first month after sowing, except in soils containing high populations of *Streptomyces*. The disease occurred from May to February, with highest incidence in late August. Single seedling infections significantly outnumbered group infections.

4. Bloomberg, W.J. 1976. Distribution and pathogenicity of *Fusarium oxysporum* in a forest nursery. Phytopathology 66(9):1090-1092.

Diseased roots of Douglas-fir seedlings, killed by Fusarium root rot in a nursery the previous growing season, were cultured to determine the presence of *F. oxysporum*, and the pathogenicity of isolates was determined in Douglas-fir seedlings. All root segments yielded the fungus and 80 percent of the isolates were pathogenic. Particulate organic matter, mainly root fragments, sawdust and unidentified particles, was collected by flotation from soil cores taken from the nursery. Most root fragments were <2 mm long and the unidentified particles were <1 mm. There was no significant difference in the distribution of any of the particle types by depth in soil. Incidence of *F. oxysporum* in all particle types was variable but significantly lower than in diseased roots. The incidence of *Fusarium* was lower in root fragments that were shorter than 4 mm. Sawdust had the lowest incidence of *F. oxysporum*. Pathogenicity of *Fusarium* species isolated from unidentified particles was lower than that of root isolates. Temperature (10 to 30 degrees C) had no significant effect on pathogenicity of *F. oxysporum* from diseased roots.

5. Bloomberg, W.J. 1976. Simulation of Douglas-fir seedling root growth, damping-off and root rot. Canadian Forestry Service, Pacific Forest Research Centre, Report BC-X-127.

A FORTRAN computer model was constructed for *Pseudotsuga menziesii* in a nursery in British Columbia. The model is an integrated system with four components: seedling attributes; environmental factors; pathogen (*Fusarium oxysporum*) behavior; and the disease process. A simplified flow chart and modelling procedures are given. Model predictions in two seasons amounted to 72 to 121 percent of actual nursery results. Applications include determination of optimum timing for root pruning, fertilizer application, etc., and disease prediction.

6. Bloomberg, W.J. 1979. A model of damping-off and root rot of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 69:74-81.

The mathematical relationships required to construct a model of damping-off and root rot of Douglas-fir seedlings caused by *Fusarium oxysporum* were derived from the literature, unpublished data, and experiments. A time and space frame of 180 days from sowing, in plots 0.1 to 0.2 m^2 x 20 cm deep containing up to 100 seedlings, was selected. Simplifications and assumptions in the model included use of temperature as the main environmental factor, subdivision of time into 5-day periods and space into 2 cm intervals, with one vertical and one horizontal dimension, and natural variation based on pseudo-random selections from normal distributions. Using chi-squared goodness-of-fit, model predictions of germination, root growth and root rot mortality were not significantly different from nursery results in 4 years. Predictions of number of seedlings and seedling roots infected ranged from 72 to 120 percent of nursery results.

7. Bloomberg, W.J. 1979. Model simulations of infection of Douglas-fir seedlings by *Fusarium oxysporum*. Phytopathology 69:1072-1077.

A simulation model of Fusarium root rot of *Pseudotsuga menziesii* seedlings was used to predict seedling infection, mortality, root growth in various temperature regimes, root growth rates and sizes, and concentrations of inoculum. The most important factors in simulated root infection were those affecting size and number of infection sites (root tips), size and concentration of inoculum particles, and rate of lesion elongation. More and longer root tips per seedling, more infection, more rapid spread of lesions in roots, and more seedling mortality were predicted by simulations with warm regimes than by those with moderate or cool regimes. Simulations with fast root growth rates also predicted more and longer root tips and infections than did those with slow or moderate root growth rate but no increase in rate of lesion spread or seedling mortality. Simulations with relatively long or thick inoculum particles or relatively dense inoculum concentrations predicted more root infection and seedling mortality than did those with small particles or sparse concentrations. According to model predictions, density of inoculum in the upper 10 cm of soil had a greater effect on infection and seedling mortality than density in the lower 10 cm. The rapidity with which the taproot be-

came infected and the proximity of infections to the upper part of the the taproot were the most important factors in seedling mortality. Predicted root length was affected most by rate of root elongation, number of infections and rate of lesion elongation.

8. Bloomberg, W.J. 1981. Disease caused by *Fusarium* in forest nurseries. IN: *Fusarium*: diseases, biology, and taxonomy, p.178-187. Edited by P.E. Nelson, T.A. Toussoun, R.J. Cook. Pennsylvania State University Press.

   Reviews disease types, distribution, pathogenicity, races and strains, damage, environmental factors, and control.

9. Bloomberg, W.J. and W. Lock. 1972. Strain differences in *Fusarium oxysporum* causing diseases of Douglas-fir seedlings. Phytopathology 62:481-485.

   Axenically grown Douglas-fir seedlings were inoculated with *Fusarium oxysporum* isolates obtained in a nursery from roots of healthy Douglas-fir seedlings or from roots of seedlings infected with pre-emergence damping-off, postemergence damping-off, root rot, or corky root. All isolates killed all seedlings, but there were significant differences among isolates in the chronological pattern of mortality they produced. In seedlings growing in controlled environments in naturally infested soil, there was not significant association between any one disease caused by *F. oxysporum* and another. In nurseries, there were no significant correlations between the levels of one disease and another.

10. Bloomberg, W.J. and W. Lock. 1974. Importance of treatment timing in the control of Fusarium root rot of Douglas-fir seedlings. Phytopathology 64(8):1153-1154.

    In nursery trials in 1972 and 1973, seedlings of *Pseudotsuga menziesii* were treated with captan at various times after sowing. Two soil drenches of an aqueous suspension of the fungicide, applied 20 and 40 days after sowing, significantly reduced the number of seedlings killed by *Fusarium oxysporum*.

Disease incidence was not reduced by applying the dry chemical at the time of sowing, or by drenching at 10 and 20 days after sowing. The results indicate that the critical period for root infection extended up to 10 days after emergence, i.e. ca. 30 to 40 days after sowing.

11. Bloomberg, W.J. and W.R. Orchard. 1969. Chemical control of root disease of Douglas-fir seedlings in relation to fungus and nematode populations. Annals of Applied Biology 64:239-244.

Seed treatment with thiram reduced post-emergence damping-off, while fumigating forest nursery soils with methyl bromide or DD® improved Douglas-fir seedling emergence, shoot and root growth, and decreased the incidence of root disease. At an old site, where corky root develops, the benefits from these fumigants were associated with fewer (a) *Xiphinema bakeri* and (b) isolates of *Cylindrocarpon radicicola.* At a new site, decrease in Fusarium root rot and increase in shoot growth were related to reduction of populations of *Paratylenchus* and *Pratylenchus*, respectively. In unfumigated soils, *Fusarium oxysporum* was isolated from diseased and healthy roots.

12. Bynum, H.H. 1970. Biological evaluation: Bend nursery seedling mortality. USDA Forest Service, Pacific Northwest Region.

In past years, the Bend pine nursery has experienced excessive losses of ponderosa and lodgepole pine seedlings. Investigations have attributed much of this loss to Fusarium root rot, and large populations of *Fusarium* and *Pythium* species have been found in the Bend nursery soil. Recommendations are made for fumigation of the nursery beds in 1971 so that acceptable production of tree seedlings can be accomplished.

13. Campbell, W.A., F.F. Hendrix, Jr., and W.M. Powell. 1972. *Pythium* and nematode species implicated in root rot. Tree Planters' Notes 23(1):5-7.

Recurring root rot at the Bend, Oregon, nursery stimulated efforts to find the cause and possible remedial measures. Earlier studies has implicated *Fusarium oxysporum* as the cause

of root rot on ponderosa pine. Soil samples from the nursery were assayed for *Pythium*, *Phytophthora* and nematodes. No *Phytophthora* spp. were recovered, but *Pythium* populations were relatively high. Isolations from diseased fine roots of nursery stock invariably result in the recovery of *Fusarium* spp. to the the near exclusion of *Pythium* species. This pattern seems to indicate that the *Pythium* species, which attack only very succulent fine roots, open the way for greater root damage from *Fusarium* species.

14. Cooley, S.J. 1982. Soil solarization in a forest nursery for the control of nursery pests. USDA Forest Service, Pacific Northwest Region, Forest Pest Management.

A new soil treatment, solarization, was compared to soil fumigation and no treatment in an eastern Oregon conifer nursery. Seedling survival, weed reduction, and populations of soil fungi and nematodes were evaluated in all treatments. Fumigation resulted in superior survival and stand of ponderosa pine seedlings during the first 10 weeks after emergence. Seedling survival in solarized areas was similar to that in check areas. Weed control was best in fumigated and poorest in check plots. Both fumigation and solarization resulted in lowered populations of *Fusarium* spp. and several groups of nematodes when sampled immediately after treatment. Soil temperatures at depths of 5, 15, and 30 cm were at least 10 degrees higher during solarization than temperatures in nonsolarized soil. Operational use of solarization cannot be recommended until further solarization trials show levels of pest reduction and seedling survival similar to those seed with fumigation. The causes for poor performance in solarized plots are discussed.

15. Cooley, S.J. 1983. Fungicide trials on sugar pine at a southern Oregon nursery. Tree Planters' Notes 34(3):15-18.

Treatment of sugar pine seedbeds with the fungicides captan, benomyl, and Banrot® did not consistently reduce losses from Fusarium root rot.

16. Cooley, S.J. 1985. Evaluation of solarization and fumigation at the J. Herbert Stone Nursery. USDA Forest Service, Pacific Northwest Region.

Fumigation and solarization were compared at the J. Herbert Stone Forest Nursery in southwest Oregon for disease and weed control. Fumigation resulted in significantly reduced levels of weeds and disease. Solarization, while reducing the number of weeds, did not decrease disease severity. Possible reasons for poor disease control with solarization are discussed.

17. Cooley, S.J. 1985. Solarization in two Pacific Northwest forest nurseries. IN: USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.45-48. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

18. Cooley, S.J. and B. Kelpsas. 1988. Comparison of 3 soil fumigants in a bareroot conifer nursery. Tree Planters' Notes (in press).

Nursery soil was treated with dazomet (Basamid®), metam sodium (Soil Prep®), methyl bromide chloropicrin (Dowfume MC-33®) or left untreated. All three chemical treatments resulted in reduced levels of pathogenic fungi in the soil and improved ponderosa pine seedling survival and stand density. Seedling growth was the same regardless of treatment or no treatment in the first growing season. Some growth differences were seen after the second growing season. Height and caliper variation was least with the dazomet treatment. Utilization of these chemicals in conifer nurseries is discussed.

19. Danielson, R.M. and C.B. Davey. 1969. Microbial recolonization of a fumigated nursery soil. Forest Science 15(4):368-380.

Soil fumigation with methyl bromide resulted in the dominance among the fungi of *Trichoderma* species and *Penicillium piscarium* in both the soil and rhizosphere. The inoculum source was a pine needle mulch applied following fumigation. Application of a microbiologically different mulch resulted in a different fungal population which was still detectable after 4 months. The fungal population in the subsurface soil remained at a very low level throughout the study period of 7 months. The bacteria responded immediately and strongly to fumigation. Numbers in the subsurface soil subjected to high levels of methyl bromide exceeded the numbers in the controls 10 to 20 times immediately after removal of the fumigation covers. Their populations fell sharply but remained above the control populations throughout the study. The fungal species isolated from the rhizosphere were the same as those isolated from the soil, but 7 of the 19 species isolated from surface-sterilized roots were not recorded from either the soil or rhizosphere. Larger numbers of fungi in genera known to include plant pathogens were isolated from the surface-sterilized root tips of seedlings grown in nonfumigated soil than from fumigated soil. Clamp-bearing basidiomycetes were isolated from roots from all treatments. Histological and morphological examinations of roots indicated that fumigation delayed mycorrhiza formation for several weeks and altered the fungal symbionts involved.

20. James, R.L. 1984. Evaluation of fungicides to control root disease at the Champion Timberlands Nursery, Plains, Montana. USDA Forest Service, Northern Region, Forest Pest Management Report 84-9.

Metalaxyl, Banrot®, captan, and benomyl were evaluated to reduce mortality of lodgepole pine, ponderosa pine, and Douglas-fir seedlings due to damping-off and root disease at the Champion Timberlands Nursery. Fungicides were applied as drenches before sowing and after seedling emergence. Seedling mortality and soil populations of *Fusarium* and *Pythium* were measured. Metalaxyl was the most effective fungicide in improving seedling survival. All fungicides initially reduced population levels of *Fusarium* and *Pythium* in the soil; however, levels increased in presence of susceptible conifer

seedlings throughout the first growing season. Soil fungicides should only be used if the need to control damping-off and root disease has been clearly demonstrated and other more effective measures cannot be used.

21. Johnson, D.W. 1975. The major causes of loss of seeds sown in 1972 at the Wind River Nursery, Carson, Washington. Tree Planters' Notes 26(3):14-15, 28.

    Analyzes in detail the germination, survival, and growth during 1972-73 of seedlings of 13 coniferous seedlings raised from sowings in spring 1972 at this long-established nursery, which is an important source of softwood planting stock (80 percent Douglas-fir) but has proved susceptible to serious recurrent losses. Low winter temperatures, leading to frost-heaving, were the main cause of the plant losses recorded; other factors included damping-off and root rot. Preventive measures are discussed, and further research on the stratification of seed of *Abies* species is recommended.

22. Johnson, D.W. and C.A. Bigelow. 1973. Effects of soil treatments on fungal populations and ponderosa pine seedling survival at the Bend Nursery. USDA Forest Service, Pacific Northwest Region.

    Excessive losses of seedlings to root rots, caused by a root disease complex involving species of *Pythium* and *Fusarium*, have been noted at the nursery since 1948. Several treatments have been tried but none consistently reduced damage by these fungi. This study attempts to determine the effects of fumigation, sulfur, sawdust and combinations of them to reduce losses and the relationship between population estimates of *Pythium* spp. and *Fusarium* spp. and ponderosa pine seedling emergence and survival.

23. Johnson, D.W. and R.D. Harvey, Jr. 1973. Evaluation of seed protectant fungicides for control of Douglas-fir and ponderosa pine seedling root rots. USDA Forest Service, Pacific Northwest Region.

    The Wind River and Bend Forest Service nurseries in Washington and Oregon have periodically suffered large losses of

seedlings to root rot fungi. Several promising seed protectant materials were evaluated in controlled environmental chamber tests for their effectiveness in preventing losses of *Pseudotsuga menziesii* and *Pinus ponderosa* seedlings in preemergence and postemergence damping-off and later root rot. The seed treatments, particularly Arasan 75®, Dexon 35® and Preseed® provided some protection against damping-off, but not the later stages of root rot caused by *Fusarium* spp. Approximately 3 weeks after sowing the seeds, survival of emerged seedlings decreased in response to Fusarium root rot. Losses continued until the sixth week, after which little mortality occurred.

24. Johnson, D.W. and R.D. Harvey, Jr. 1975. Seed-protectant fungicides for control of Douglas-fir and ponderosa pine seedling root rots. Tree Planters' Notes 26(2):3-5.

    Reports results of laboratory trials with seeds of *Pseudotsuga menziesii* and *Pinus ponderosa* sown in soils from two nurseries in Washington and Oregon infected with species of *Pythium* and *Fusarium*. Treatment of the seeds with thiram, fenaminosulf or Preseed® gave some protection against early damping-off, but no protection against later root rot. Benomyl and captan gave little or no protection.

25. Johnson, D.W. and B. Zak. 1977. Effects of soil treatments on fungal populations and ponderosa pine seedling survival in an Oregon nursery. Plant Disease Reporter 61(1):43-47.

    Soil fumigation, soil acidification, and the addition of organic matter were evaluated for effectiveness in reducing losses of ponderosa pine seedlings to Pythium and Fusarium root rots in an Oregon nursery. Soil fumigation and addition of organic matter provided greater disease control than either soil fumigation or organic matter alone. Soil acidification with sulfur did not control the disease or reduce populations of pathogenic fungi.

26. Landis, T.D. 1976. Fusarium root disease of containerized tree seedlings, Colorado State Forest Service Nursery. USDA Forest Service, Rocky Mountain Region, Forest Insect and Disease Management, Biological Evaluation R2-76-16.

Reviews the results of a survey conducted of the containerized Douglas-fir and pinyon pine seedlings which were experiencing heavy mortality. Fusarium root rot was confirmed to be the cause. Recommendations are made for prevention of the disease in future crops.

27. Lock, W. 1973. Fusarium root rot of Douglas-fir nursery seedlings. Canadian Forestry Service, Forest Insect and Disease Survey, Pest Leaflet 61.

    Short notes on the hosts (including *Pinus ponderosa* and *Larix occidentalis*), distribution and life history of *Fusarium oxysporum* f. sp. *pini*, symptoms of attack and damage caused, and fumigants for control.

28. Lu, K.C. 1968. Effect of organic amendments on soil microflora in relation to Fusarium root rot of ponderosa pine seedlings. IN: Western Forest Nursery Council, Proceedings, 1968, p.41-43.

    The purpose of the study was to investigate the effects of adding various organic materials to the soil, to promote growth of appropriate antagonistic microorganisms as substitutes for chemical in the control of root disease. Pine litter, bark and sawdust incorporated into the nursery soils at 10 tons per acre have a positive effect in reducing seedling disease. Microbial populations in all amended plots were significantly higher than those of the control plot, possibly accounting for the reduction in disease in the amended areas.

29. Marshall, J.P. 1985. Pre- and post-fumigation assay for plant pathogens, Lucky Peak Forest Nursery, Idaho. USDA Forest Service, Intermountain Region, Forest Pest Management Report 85-9.

    The purpose of this evaluation was to identify soil-borne plant pathogens, estimate their population levels within the upper 0.0 to 15.24 and 15.24 to 30.48 cm of soil prior to and following fumigation, and to determine pathogenicity of isolated species. Results show that fumigation with 67 percent methyl bromide and 33 percent chloropicrin is effective in reducing *Fusarium* spp. levels in the upper 30.48 cm of soil.

30. Merrill, W., K. McCall and L. Zang. 1981. Fusarium root rot of Douglas-fir and Fraser fir in Pennsylvania. Plant Disease 65(11):913-914.

Root rot of *Pseudotsuga menziesii* and *Abies fraseri* seedlings caused by *Fusarium solani* and of the former by *F. oxysporum* is reported from Pennsylvania. During their second growing season Douglas-fir nursery seedlings became stunted and chlorotic, wilted and died. Mortality was 50 percent in four nurseries; another 25 to 50 percent of the remaining seedlings were stunted, had poorly developed root systems and probably would not have survived planting out. In one nursery, greater than 90 percent of the Douglas-fir seedlings died late in their first growing season. In a single seedbed of Fraser fir next to a severely affected Douglas-fir seedbed, 15 percent of the second year seedlings died. *F. solani* was recovered from roots with cortical root rot.

31. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Fusarium root rot.

32. Sinclair, W.A., D.P. Cowles, and S.M. Hee. 1975. Fusarium root rot of Douglas-fir seedlings: suppression by soil fumigation, fertility management, and inoculation with spores of the fungal symbiont *Laccaria laccata*. Forest Science 21(4):390-399.

Mortality of Douglas-fir seedlings caused by *Fusarium oxysporum* in nursery beds was lessened by soil fumigation and increased by applications of urea fertilizer. Losses were directly related to amount of urea applied (0 to 112 kg N/ha), regardless of timing (before or up to 11 weeks after sowing seed). Mortality rates were temporarily lower in plots inoculated at or shortly after sowing time with basidiospores of the ectomycorrhizal fungus *Laccaria laccata* than in noninoculated plots. This treatment did not influence subsequent mycorrhizal formation. A factorial experiment showed that growth of

seedlings during the first season was increased by presowing addition of 179 kg/ha of P in superphosphate but not by up to 168 kg/ha N from urea or up to 134 kg/ha K from potassium sulfate. Root rot losses were least where nitrogenous fertilizer was withheld during the first growing season. Infected seedlings were stunted but many remained alive. With biweekly application of nitrogenous fertilizer in the second season, previously stunted seedlings grew nearly as large as seedlings that had remained healthy during the first year period of susceptibility. These findings imply that (a) further research on inoculation with mycorrhizal fungi should focus upon establishment of the fungal symbiont; (b) through soil fumigation and fertility management, losses of Douglas-fir seedlings in nurseries to Fusarium root rot can be reduced to acceptable levels while quality of the final seedling crop is maintained.

33. Smith, R.S., Jr. 1967. Decline of *Fusarium oxysporum* in the roots of *Pinus lambertiana* seedlings transplanted into forest soils. Phytopathology 57(11):1265.

Following observations of root disease and *F. oxysporum* infection on seedlings planted out in the Sierra Nevada, and the absence of the fungus, and indeed of most Fusaria, on native seedlings, 1-year-old nursery-grown sugar pine were planted and stratified seeds sown in an opening in a *Pinus lambertiana/ Abies concolor* stand in the Sierra Nevada. Over a 4-year period, no *F. oxysporum* was found on the area where stratified seeds were sown or on native seedlings. In the area where nursery-grown seedlings were planted, the percent of roots yielding *F. oxysporum* declined from an initial 90 percent to 39 percent in the following summer and none in the autumn of the fourth year, suggesting that the absence of *F. oxysporum* in the field may be due not only to lack of past introduction but to an unfavorable environment.

34. Stack, R.W. and W.A. Sinclair. 1974. Protection of Douglas-fir seedlings against Fusarium root rot by a mycorrhizal fungus. Phytopathology 64(5):586.

Reports experiments in which seedlings of *Pseudotsuga menziesii* were protected by adding *Laccaria laccata* (an ectomycorrhizal

symbiont) to soil infested with *Fusarium oxysporum*. The dry weight of seedlings 13 weeks after sowing in pasteurized soil was reduced by 52 percent with the addition of *F. oxysporum*, but only 15 percent with the addition of *F. oxysporum* plus *L. laccata*. The best results were obtained when *L. laccata* was introduced at a depth of 3 cm and *F. oxysporum* at 6 cm. The addition of spores of *L. laccata* to nursery soil infected with *F. oxysporum*, at the time of sowing, reduced seedling mortality during the first growing season from 5.6 percent to 2.4 percent. The protective influence of *L. laccata* began before mycorrhizae were formed.

35. Stack, R.W. and W.A. Sinclair. 1975. Protection of Douglas-fir seedlings against Fusarium root rot by a mycorrhizal fungus in the absence of mycorrhiza formation. Phytopathology 65(4):468-472.

    Pseudotsuga menziesii seedlings inoculated in a controlled environment chamber with *Fusarium oxysporum* from a forest nursery developed root rot, had a high mortality rate and grew poorly. When basidiospores of the mycorrhizal fungus *Laccaria laccata* were placed between seedling roots and inoculum of *F. oxysporum* in the mixture of soil, sand and perlite or vermiculite, less mortality and root rot occurred than in treatments receiving only *F. oxysporum* inoculum or *F. oxysporum* inoculum placed between roots and *L. laccata* spores. Mycelium of *L. laccata* prevented detrimental effects of *F. oxysporum* when placed in the soil mixture near seedling roots 1 to 3 weeks before the introduction of *F. oxysporum*. Formation of mycorrhizae was not a prerequisite for the protective influence of the mycorrhizal fungus.

36. Strobel, N.E. and W.A. Sinclair. 1987. Protection of Douglas-fir seedlings by *Laccaria bicolor* against root rot caused by *Fusarium oxysporum* is conditioned by temperature and aggressiveness of the pathogen. Phytopathology 77(11):1619.

    Pseudotsuga menziesii seedlings grown in petri dishes containing an agar rooting medium were evaluated for incidence and severity of root rot caused by *F. oxysporum* as conditioned by temperature, aggressiveness of isolate, site of inoculation and prior exposure of the primary roots to the ectomycorrhizal

fungus *Laccaria bicolor.* Three isolates of *F. oxysporum* displayed differential aggressiveness when inoculated to root tips or to differentiated tissues at 17 degrees C, but all three caused extensive decay of roots and hypocotyls at 22 degrees C. Prior exposure to roots to *L. bicolor* suppressed the incidence and extent of root colonization by the least aggressive isolate of *F. oxysporum* at 17 degrees C but not at 22 degrees C and did not affect colonization by the other isolates.

37. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p. 203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

    A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

38. Sutherland, J.R. and R.L. Anderson. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. IN: North American Forest Tree Nursery Soils Workshop, Proceedings, p.182-190. Held July 28-August 1, 1980.

    Soil conditions play a major role in preventing or causing devastating losses from many nursery disease and insect problems. This paper reviews the relationships between several soil factors, cultural practices, and certain disease and insect problems.

39. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

Reviews hosts, damage, life history and control of various nursery diseases, including Fusarium root rot.

40. Sylvia, D.M. and W.A. Sinclair. 1981. Phenolics induced by *Laccaria laccata* are associated with resistance to *Fusarium oxysporum* and *Pythium irregulare* in primary roots of Douglas-fir seedlings. Phytopathology 71(8):907.

Primary roots of 1-month-old seedlings of *Pseudotsuga menziesii*, untreated or inoculated with the ectomycorrhizal fungus *Laccaria laccata*, were challenged with *Fusarium oxysporum* or *Pythium irregulare*. As the pathogens grew from infested seeds across agar coated slides to roots, their rates of growth and their levels of rhizoplane colonization were not influenced by *L. laccata*. Thus antibiosis may have no role in the interaction. However, colonization of the root cortex by each pathogen was significantly inhibited in roots previously exposed to *L. laccata*. Hyphal frequency was inversely proportional to the concentration of phenolics that developed in roots exposed to either the *L. laccata* or its metabolites. Phenolics induced by *L. laccata* are thus associated with a resistance that protects seedlings from damaging fungal infections.

41. Thies, W.G. 1976. Evaluation of fumigation with methyl bromide-chloropicrin to reduce the number of propagules of *Pythium* spp. and *Fusarium* spp. in seedbeds at the Bend Nursery. USDA Forest Service, Pacific Northwest Region.

The purpose of this evaluation was to determine the post-fumigation residual propagule populations of *Fusarium* spp. and *Pythium* spp. at specific points in the soil profile. Results show that the residual population of *Fusarium* spp. is large enough to allow return to pre-fumigation levels during one crop rotation, necessitating fumigation before another crop of tree seeds is sown.

42. Toussoun, T.A. 1975. *Fusarium*-suppressive soils. IN: Biology and control of soil-borne plant pathogens, p.145-151. Edited by G.W. Bruehl, American Phytopathological Society.

A historical review of works on *Fusarium*-suppressive soils, including the work of R.S. Smith, Jr. in conifer forests in California.

43. Toussoun, T.A., W. Menzinger and R.S. Smith, Jr. 1969. Role of conifer litter in ecology of *Fusarium*: stimulation of germination in soil. Phytopathology 59(10):1396-1399.

Water extracts of ponderosa pine, sugar pine, white fir, and coast redwood litter stimulated the germination of macroconidia and chlamydospores of *Fusarium oxysporum*. Germination of chlamydospores of *F. oxysporum*, *F. oxysporum* f. sp. *vasinfectum*, *F. solani*, and *F. solani f.* sp. *phaseoli* was also enhanced in conifer soils, and reached 95 to 98 percent. When ponderosa litter extract was compared with 1 percent glucose and 2.5 percent asparagine solutions on chlamydospores of *F. oxysporum* in soil, greater germination was obtained with the litter extract. But in conifer soils, the germination generally resulted in the production of abnormal germ tubes that lysed rapidly before new chlamydospores were formed. It is postulated that germ tube lysis of such a large proportion of the population may account, in part, for the general absence of *Fusarium* spp. in conifer forest soils in California.

44. Vaartaja, O. 1967. Reinfestation of sterilized nursery seed beds by fungi. Canadian Journal of Microbiology 13:771-776.

Incidences of soil fungi were recorded for 1 cm^3 volumes of untreated and fumigated nursery soils using new selective isolation media. In July, 10 months after application of Trizone® at 1 lb/100 ft^2, there were many viable *Pythium* propagules in the treated surface soil (11/cm^3) but significantly fewer than in nonfumigated soil (29/cm^3). Studies with baits showed that *Rhizoctonia* and *Fusarium* spp. were also present in both soils. The total number of fungi in fumigated soil (11,000) was lower than in nonfumigated soil (30,000). *Trichoderma* propagules were very common and significantly more so in fumigated

(1,120) than in nonfumigated (270) soil. The same held for bacteria (10 million vs. 7 million). Reinfestation with four potentially pathogenic genera of fungi was found to take place by means of splashing rain and irrigation water, dust, and soil carried by workers.

45. Vaartaja, O. and P.J. Salisbury. 1965. Mutual effects in vitro of microorganisms isolated from tree seedlings, nursery soil, and forests. Forest Science 11(2):160-168.

Selected isolates of actinomycetes and fungi imperfecti isolated from tree seedlings, nursery soils, and basidiomycetes isolated from fruiting bodies were paired on cornmeal agar, and the mutual effects recorded. In the majority of 1,205 different combinations, antagonism was present, but in many there were no mutual effects. Stimulation took place very seldom. The most common effect was the inhibition of growth for a distance of 0 to 20 mm. Very often the growth of the colony was inhibited on contact or soon thereafter. Lysis was observed in several cases. Although antagonism or sensitivity to antagonism was typical of many isolates, it was lacking in certain combinations of each isolate. Isolates of the following genera were among those usually exhibiting strong antagonism: *Armillaria, Bacterium, Cylindrocarpon, Gliocladium, Penicillium, Russula, Streptomyces, Suillus,* and *Trichoderma.* Many species of *Fusarium, Gliocladium* and *Streptomyces* were the most insensitive isolates and several basidiomycete and phycomycete isolates were the most sensitive.

46. Williams, R.E. 1975. Nursery conifer diseases - evaluation of benomyl to control root disease of Engelmann spruce seedlings. USDA Forest Service, Northern Region, Report 75-15.

The benomyl fungicide, Tersan®, applied at 7 and 14 lb a.i./ acre, was ineffective in reducing mortality in 2+0 *Picea engelmannii.* Higher rates of application, 28 and 42 lb a.i./acre, applied during a second treatment period, were also ineffective. Bioassay studies to determine chemical distribution in soil and within seedlings were generally negative. Reasons for lack

of control and negative assays are discussed. Isolation studies did reveal a high frequency of occurrence of *Fusarium* spp. in dead seedlings, and disease expression increased with increasing summer temperatures, implicating fusarial pathogens in the causal complex.

47. Wright, E. 1957. Compendium of root-rot studies at the Bend Forest Service nursery. USDA Forest Service. Pacific Northwest Forest and Range Experiment Station.

    Summarizes experiments to control root-rot losses in the Bend nursery from 1949 through 1956.

48. Wright, E. 1964. Effect of fumigation with Trizone® on microbial properties of soil and growth of seedlings. Down to Earth 20(1):13-15.

    Trizone® soil fumigant applied to nursery soil near Corvallis and Bend, Oregon, resulted in increased growth of *Pseudotsuga menziesii* and *Pinus ponderosa* seedlings and reduced population of Fusarium root rot in trials made to improve production in forest nurseries. Previous tests of chloropicrin at high concentrations led to stunting of ponderosa pine seedlings. Larger tests with Trizone® proved less drastic and more satisfactory.

49. Wright, E., G.M. Harvey and C.A. Bigelow. 1963. Tests to control Fusarium root rot of ponderosa pine in the Pacific Northwest. Tree Planters' Notes 59:15-20.

    Fusarium root rot of ponderosa and other species of pine has been a serious problem in at least two forest nurseries in the interior of Oregon and California. Typically, the disease kills 1- to 3-month-old seedlings by girdling the taproot at the ground line or just below the root crown. This report covers many series of tests in seedbed and greenhouse made over a number of years to determine the best method of control. Parallel tests in the greenhouse were run to determine the pathogenicity of the *Fusarium* and the effect of soil temperature on virulence of the parasite.

Gray Mold
(*Botrytis cinerea*)

We include 26 references on gray mold in the bibliography. The vast majority are from the Pacific Northwest or western United States. The hosts on which work has been carried out include Douglas-fir, lodgepole pine, Engelmann spruce, western larch, redwood, and sequoia in both container and bareroot nurseries. Most of the references deal with chemical management of the disease; about one-third of these report trials to determine the tolerance of gray mold isolates to various fungicides (5, 6, 7, 10, 14, 15). We list one general reference on the biology of *Botrytis* on many hosts (4); little or no work has been published specifically on the biology of *Botrytis* on conifers. Various combinations of chemical and cultural strategies are reported in two references (2, 24) and general biology and management are covered in four other publications (12, 21, 22, 25).

1. Anonymous. 1981. Soaps making a comeback on pest control scene. Canadian Forestry Service, Pacific Forest Research Centre, Information Forestry 8(1):6-8.

   Dr. George Puritch is studying the use of fatty acids for insect and disease control. Aphids, earwigs, mealybugs, mites, and white flies, as well as several disease organisms, have been controlled by applications of soap. Research is being done on fungicidal soap which will control root rots and *Botrytis*.

2. Bloomberg W.J. 1966. Grey mould of Douglas-fir seedlings. Canadian Forestry Service, Bi-Monthly Research Notes 22(4):7.

   Grey mold of Douglas-fir seedlings caused by *Botrytis cinerea* occurs sporadically in forest nurseries of coastal British Columbia. The climatic events most likely to promote the disease are a warm period in early spring causing the needles to flush, followed by a cool humid period which delays their maturation. The sporadic occurrence of the disease makes the application of routine control practices difficult. In tests of various chemicals for their effectiveness against grey mold, ferbam, and thiram were highly effective, zineb was partially effective, and Bordeaux mixture stimulated the disease.

3. Carlson, L.W. 1972. Forest tree nursery disease control. IN: Western Forest Nursery Council and Intermountain Forest Nurserymen's Association, Proceedings of Joint Meeting, 1972, p.111-114. Edited by H.W. Anderson, J.A. Bryan, R.P. Eide. Held August 8-10, 1972, Olympia, Washington.

Reviews chemical and cultural practices for control of the major disease problems: damping-off, gray mold, Lophodermium, and storage molds.

4. Coley-Smith, J.R., K. Verhoeff, and R. Jarvis, editors. 1980. The biology of *Botrytis*. Academic Press, New York. 30pp.

This comprehensive book reviews the genus *Botrytis*. Chapters cover taxonomy; variation in *Botrytis* and *Botryotinia*; formation, structure and germination of conidia; sclerotia and other structures in survival; behavior of conidia on aerial plant surfaces; infection process and host-pathogen interactions; mechanisms of resistance to *Botrytis*; epidemiology; *Botrytis cinerea* in enology; and disease control.

5. Cooley, S.J. 1981. Fungicide tolerance of *Botrytis cinerea* isolates from conifer seedlings. USDA Forest Service, Pacific Northwest Region.

Twenty-four *Botrytis cinerea* isolates from Pacific Northwest forest nurseries were grown on fungicide-amended media. Each isolate was tested for tolerance to seven fungicides. Overall, dichloran (Botran®) was most inhibitory; variable inhibition occurred with benomyl (Benlate®), captan (Captan®), chlorothalonil (Daconil 2787®), and vinclozolin (Ronilan®); and all were tolerant to some extent to mancozeb (Dithane M-45®). Isolates showing tolerance to dichloran and captan generally were more tolerant to other fungicides than were isolates sensitive to dichloran and captan. Grey mold management alternatives in forest nurseries are discussed.

6. Gillman, L.S. and R.L. James. 1978. Fungicidal tolerance of *Botrytis cinerea*. IN: Western Forest Nursery Council and Intermountain Nurseryman's Association, Conference and Workshop Proceedings, 1978, p.B143-B153, edited by R.W. Gustafson. Held October 1978, Eureka, California.

   Numerous *Botrytis cinerea* isolates from containerized conifers within three Colorado nurseries exhibited levels of tolerance to commercially-used fungicides. Some isolates were tolerant to benomyl, captan, chlorothalonil, mancozeb, and zineb during in vitro growth tests on agar medium. Dichloran was the only fungicide that was completely inhibitory to all isolates tested. Benomyl at 50 ppm did not inhibit conidial germination on agar, although germ tube growth of sensitive isolates was restricted. These results indicate that *B. cinerea* isolates have developed tolerance to many commercial fungicides. Prescriptions for fungicide application should be based on tolerance characteristics of isolates present.

7. Gillman, L.S. and R.L. James. 1980. Fungicidal tolerance of *Botrytis* within Colorado greenhouses. Tree Planters' Notes 31(1):25-28.

   Botran® (dicloran) was the only fungicide tested that completely inhibited growth in vitro of *Botrytis cinerea* isolated from container grown Coniferae seedlings from three greenhouses. The isolates showed some degree of tolerance of benomyl (two formulations), captan, Daconil 2787® (chlorothalonil), Dithane M-45® (mancozeb) and Dithane Z-78® (zineb).

8. Glover, M.M., J.R. Sutherland, C.L. Leadem, and G. Shrimpton. 1987. Efficacy and phytotoxicity of fungicides for control of Botrytis gray mould on container-grown conifer seedlings. Canada - British Columbia Forest Resources Development Agreement, FRDA Report 012.

   The fungicides anilazine, captan, dichloran, folpet, iprodione, and thiram were tested for efficacy against gray mold, *Botrytis cinerea*, on container-grown seedlings of white spruce, western red cedar, western hemlock, Sitka spruce, and Douglas-fir. Phytotoxicity of the fungicides to the seedlings was also determined. Beginning in the 14th week after germinant emergence,

the fungicides were applied biweekly for the next 2 months. To ensure that adequate inoculum of the pathogen was present, the seedlings were inoculated with a mixture of 10 isolates of *B. cinerea* after the first fungicide application, and on alternate weeks thereafter, for a total of six inoculations. Growth of all species except Douglas-fir was inhibited by one or more of the fungicides. Iprodione gave excellent *Botrytis* control on all species. Anilazine gave adequate control on all species except Douglas-fir and western red cedar, and some needle browning was observed on both spruce species. Gray mold control on western red cedar was excellent with thiram, and good on all other species except western hemlock. Folpet gave good control of *Botrytis* on Douglas-fir and Sitka spruce. Disease control was excellent with dichloran on western hemlock and white spruce. Captan provided good control on Douglas-fir.

9. Halber, M. 1963. *Botrytis* spp. on Douglas-fir seedlings. Plant Disease Reporter 47(6):556.

   During the past few years, *Botrytis* spp. has caused occasional spotty infections of *Pseudotsuga menziesii* seedlings in the Oregon State forest nursery near Corvallis. This activity has been severe enough to prompt investigation of factors involved and the possibility of controlling the disease by spraying with the fungicide thiram.

10. Hopkins, J.C. 1984. A rapid method for determining the tolerance of gray mold to benomyl. Canadian Forestry Service, Research Notes 4(4):53-54.

    Gray mold (*Botrytis cinerea)* damages many conifer seedlings (especially when container grown) and is normally controlled by the systemic fungicide benomyl. Frequent use of benomyl, however, results in the production of tolerant isolates. Normal testing procedures for tolerance involve culture on benomyl media and take two weeks, but a method is described here which can take as little as 24 hours. Conidial clusters of *B. cinerea* from infected seedlings are inoculated onto potato dextrose agar plates containing 100 micrograms/ml benomyl and incubated at room temperature for 24 hours. Benomyl-sensitive isolates produce short, twisted conidial germ tubes of

uneven diameter, while resistant isolates produce straight, narrow and uniform germ tubes. Infected seedlings without conidial clusters have to be incubated in polyethelene bags to develop conidia before testing.

11. James, R.L. 1980. Engelmann spruce needle and twig blight at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Forest Insect and Disease Management, Report 80-21.

    Needle and twig blight of *Picea engelmannii* was investigated to determine probable causes and formulate recommendations for reducing future losses. The two major fungal genera consistently isolated from symptomatic seedlings were *Phoma* and *Botrytis*. Diseases caused by *Phoma* and *Botrytis* can usually be effectively controlled with fungicides. Chlorothalonil is registered for *Phoma* and is most effective when applied at 2-week intervals during cool, wet weather. Fungicide application has traditionally been used to control Botrytis blight; however, development of tolerance to certain chemicals by various strains of the fungus have been reported. No fungicides are currently registered for *Botrytis* at the Coeur d'Alene Nursery.

12. James, R.L. 1984. Biology and management of Botrytis blight. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-168, pp. 39-43. Intermountain Nurseryman's Association, Proceedings, 1983: The challenge of producing native plants for the Intermountain area, edited by P.M. Murphy. Held August 8-11, 1983, Las Vegas, Nevada.

    Botrytis cinerea is an important pathogen of conifer seedlings in western North America, especially in greenhouses, where high humidity and cool temperatures are favorable for fungus growth. Cultural practices are recommended and commonly used fungicides discussed. Some of these (e.g. benomyl) are no longer effective as the fungus has developed tolerance.

13. James, R.L. and D. Genz. 1983. Fungicide tests to control Botrytis blight of containerized western larch at the Champion Timberland Nursery, Plains, Montana. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 83-12.

Five fungicides were evaluated to control Botrytis blight of containerized western larch seedlings. Fungicides were applied at biweekly intervals before and after seedling inoculation with *Botrytis*. Vinclozolin caused severe phytotoxicity to seedlings, resulting in enhanced mortality and premature needle loss. Captan and chlorothalonil stunted seedlings. *Botrytis* caused very little damage in this test. Control strategies should incorporate fungicide application with cultural operations that reduce seedling susceptibility and chances for infection.

14. James, R.L. and C.J. Gilligan. 1983. Fungicidal tolerance of *Botrytis cinerea* from the Flathead Indian Reservation greenhouse, Ronan, Montana. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 83-5.

Tests were conducted to determine levels of tolerance of 10 *Botrytis cinerea* isolates to six fungicides. In vitro growth and conidial germination on fungicide-amended potato dextrose agar were used as criteria for assessing tolerance. All tested isolates were tolerant to benomyl and chlorothalonil, the fungicides routinely used in this greenhouse prior to the test. Most isolates displayed slight tolerance to captan; four were slightly tolerant to vinclozolin. Dicloran and iprodione were the most effective fungicides in limiting growth and spore germination of the *Botrytis* isolates tested. Field performance tests are needed to evaluate control efficacy of vinclozolin and iprodione. A rotating fungicide spray schedule coupled with good cultural practices such as sanitation, adequate air circulation, and limiting irrigation should provide adequate control for this disease.

15. James, R.L. and C.J. Gilligan. 1985. Resistance of *Botrytis cinerea* to vinclozolin, iprodione and dicloran. USDA Forest Service, Northern Region, Forest Pest Management Report 85-3.

    Isolates of *Botrytis cinerea* from containerized conifer seedlings from two nurseries in the northern Rocky Mountains were exposed to the fungicides vinclozolin, iprodione, and dicloran to evaluate occurrence and characteristics of resistant strains. Resistance to the three fungicides occurred in isolates not previously exposed to the chemicals. Some strains were even resistant to high fungicide concentrations. Genetic stability of these resistant strains was confirmed by growing them in the absence of fungicides. Cross-resistance among the three fungicides was common. Vinclozolin and iprodione generally inhibited spore germination more than mycelial growth; the opposite was true for dicloran. Ramifications of fungicide resistance in disease control are discussed.

16. James, R.L. and J.Y. Wood. 1984. Fungicide trials to control Botrytis blight at nurseries in Idaho and Montana. Tree Planters' Notes 35(4):16-19.

    Iprodione, chlorothalonil and captan adequately controlled *Botrytis cinerea* on containerized western larch and lodgepole pine seedlings. Benomyl and dicloran were less satisfactory and vinclozolin was highly phytotoxic to containerized larch seedlings though not to 2-0 bareroot seedlings. All the fungicides tested reduced height growth of the seedlings.

17. James, R.L., J.Y. Woo, and P.L. Malone. 1983. Evaluation of fungicides to control Botrytis blight in western larch seedbeds at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 83-6.

    Six fungicides were evaluated to control Botrytis blight of western larch. Fungicides were applied at biweekly intervals during the spring of 1982; test seedlings were inoculated with spores of *B. cinerea* twice during the evaluation period. Seedling mortality and height were recorded in October just prior to lifting. Because of overall low infection levels, no differences in seedling mortality were apparent as a result of fungicide treatment. Low infection

was likely due to drier spring weather than when outbreaks of the disease previously occurred. Most fungicides decreased seedling height, although no external indications of phytotoxicity were apparent. Several of the fungicides tested can be considered for use to control Botrytis blight in larch seedbeds.

18. James, R.L., J.Y. Woo, and J.F. Myers. 1982. Evaluation of fungicides to control Botrytis blight of containerized western larch and lodgepole pine at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Forest Pest Management, Report 82-17.

    Selected fungicides were evaluated to control Botrytis blight of containerized western larch and lodgepole pine seedlings. Fungicides were applied at biweekly intervals before and after seedling inoculation with *Botrytis*. Chipco 26019®, Daconil 2787® and Bravo 500® provided the best level of disease control. Tersan 1991® was ineffective. Several fungicides, especially Bravo 500®, restricted height growth of tested seedlings. These tests indicated that several fungicides are available to effectively control this disease when used in conjunction with proper sanitation and cultural procedures.

19. McCain, A.H. 1978. Nursery disease problems - containerized nurseries. IN: Western Forest Nursery Council and Intermountain Nurseryman's Association, Conference and Workshop Proceedings, p.B139-142, edited by R.W. Gustafson. Held October 1978, Eureka, California.

    Botrytis cinerea is the most troublesome above-ground disease. Benomyl is the fungicide of choice, except where the fungus has developed a tolerance. Chlorothalonil and mancozeb are also effective. It is desirable to alternate fungicides to reduce selection for tolerant fungi The most important below-ground pathogens are *Pythium* spp., *Rhizoctonia solani*, and *Fusarium oxysporum*. All can be eliminated from the soil by heat or chemical fumigation.

20. McCain, A.H. and P.C. Smith. 1978. Evaluation of fungicides for control of Botrytis blight of container-grown redwood seedlings. Tree Planters' Notes 29(4):12-13.

In many locations, forms of *Botrytis cinerea* tolerant to benomyl have developed, and for this reason the effectiveness of six fungicides (dicloran, chlorothalonil, mancozeb, captan, copper and thiram) was tested on *Sequoia sempervirens* seedlings under greenhouse conditions conducive to the development of the disease. Nine applications were made at 14-day intervals from June to September, with one inoculation of *Botrytis* conidia in July. At the first evaluation in September, dicloran and chlorothalonil were very effective, though all the fungicides had some effect. In November, 4 weeks after treatment ceased, only dicloran and chlorothalonil had any lasting effect; dicloran provided the best control.

21. Peterson, G.W. 1975. Diseases of containerized tree seedlings. American Phytopathological Society, Proceedings 2:30-31.

Under greenhouse conditions, *Botrytis cinerea* is the most serious pathogen, especially of Douglas-fir and western hemlock. Its control requires good air circulation and sanitation. Damping-off and chlorosis are common but less important; causes and control measures are summarized.

22. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including gray mold.

23. Smith, P.C. and A.H. McCain. 1981. Comparison of two systems of applying fungicides for the control of Botrytis blight of redwood seedlings. Tree Planters' Notes 32(1):32-33.

Botrytis cinerea of *Sequoia sempervirens* can be controlled by periodic fungicide applications. Both chlorothalonil and

dicloran are effective when applied as protectants. The purpose of this study was to compare and evaluate the effectiveness of a sprinkler irrigation system and the conventional hand sprayer in the application of fungicides. Results showed that application through the greenhouse sprinkler system was 19 times less effective.

24. Smith, R.S., Jr., A.H. McCain, and M.D. Srago. 1973. Control of Botrytis storage rot of giant sequoia seedlings. Plant Disease Reporter 57(1):67-69.

In October 1971, a severe gray mold epidemic, caused by *Botrytis cinerea,* was noted in two nursery beds of 6-month-old *Sequoiadendron giganteum* seedlings at the U.S.F.S. nursery, Placerville, California. Factors contributing to the epidemic were (a) the high susceptibility of giant sequoia seedlings to *Botrytis cinerea;* (b) a lath covering about 10 to 14 inches above the beds which hindered air circulation and maintained high humidities around the seedlings; and (c) the location of these nursery beds in a low wet area of the field. Because of the possibility of continued infection during seedling storage and shipment, a series of fungicide tests were conducted. Benomyl either as a pre-lifting field spray or post-lifting plant dip gave excellent control of this disease.

25. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

Reviews hosts, damage, life history and control of various nursery diseases, including damping-off, Fusarium root rot, Sirococcus blight, Fusarium top blight, grey mold, western gall rust, and storage molds.

26. Thies, W.G., P.W. Owston and D.C. Hansen. 1980. Effects of four fungicides on survival and growth of containerized Douglas-fir seedlings. Canadian Journal of Forest Research 10:423-425.

Several disease control strategies were tested on *Pseudotsuga menziesii* seedlings grown in a greenhouse-shadehouse facility

in western Oregon. Potting mixture was exposed to two pasteurization treatments combined factorially with four fungicides (benomyl, captan, fenaminosulf, and ethazol) and three application schedules (pregermination drench, postgermination drenches, and a combination of pregermination and postgermination drenches). Both pasteurization of the potting mixture and applications of fenaminosulf caused statistically significant phytotoxic effects.

Larch Needle Cast
(*Meria laricis*)

We list 16 references on larch needle cast. Half of these are from the Pacific Northwest dealing with western larch; the remainder are from Europe or eastern Canada on European, Japanese, hybrid or other species of larch. Six of the references report the occurrence or impact of the disease on the host (4, 5, 8, 11, 13, 16); two deal with the biology of *Meria laricis* (1, 14); three are chemical trial reports (2, 3, 9); and one looks at biological control (12). There are four articles which are general in nature, covering both the biology and management of the disease (6, 7, 10, 15).

1. Biggs, P. 1957. Studies on *Meria laricis*, needle-cast disease of larch. Forestry Commission (Great Britain), Report on Forest Research, 1957, p.102-104.

   Reviews experiments during the past year on culturing of the fungus, spore germination, and inoculation. Data from the Forestry Commission nurseries suggests that primary infection occurs on European larch, even when other species are grown. Future research is proposed on the onset and spread of the pathogen in relation to specific weather conditions.

2. Boudier, B. 1981. An attempt to control the drying-out of European larch (*Larix decidua*) needles caused by *Meria laricis* in the nursery. (Essai de lutte contre le dessechement des aiguilles du a *Meria laricis* sur melezes d'Europe (*Larix decidua*) en pepinieres.) Revue Forestiere Francaise 33(5):394-399. (IN FRENCH)

   One- or two-year-old plants were treated six times from February to June with sulphur at 600 g/100 litres, Bayleton® at 10 g/

100 litres, triforine at 33.3 g/100 litres and benomyl at 30 g/100 litres. From April to September all treatments gave good control of *Meria laricis*, but triforine was toxic to the plants. Among the treated plots, the best growth was obtained with Bayleton®. Larch seedlings transplanted into soil previously occupied by cereals remained free from *M. laricis*.

3. Cooley, S. 1981. *Meria laricis*: fungicide control and outplanting survival. USDA Forest Service, Pacific Northwest Region.

Larch needlecast, caused by *Meria laricis*, was reduced by fungicide treatments. Benomyl and maneb appeared to give best protection, followed by ziram, ferbam, and vinclozolin. However, differences among all treatments and no treatment were statistically insignificant. Survival of 150 seedlings from heavily infected nursery beds was 85 percent three months after outplanting.

4. Cooley, S.J. 1984. *Meria laricis* on nursery seedlings of western larch in Washington. Plant Disease 68(9):826.

The fungus is newly reported on nursery seedlings, causing severe discoloration and defoliation of 2-year-old *Larix occidentalis* and resulting in the culling of one-third of 140,000 plants.

5. Dubreuil, S.H. 1982. Western larch needle blight and needle cast in the Northern Region. USDA Forest Service, Northern Region, Forest Pest Management, Report 82-9.

Epidemics of *Larix occidentalis* needle diseases caused by *Hypodermella laricis* and *Meria laricis* occur periodically in the Northern Region. Damage from Hypodermella blight appears in mid-May to mid-June. Blighted leaves remain attached to spur shoots. Rainfall during leaf expansion favors spore production and infection. Meria needlecast increases defoliation throughout summer as long as periodic rainfall occurs. Leaves are shed 2 to 4 weeks after infection. Damage includes (1) radial growth loss equal to the amount of defoliation, (2) death of some seedlings after 2 or 3 successive years complete defoliation, (3) seedling height growth reduction from terminal

shoot death, and (4) root mortality, which can predispose trees to root pathogens. Bordeaux mixture can be used to reduce damage in nurseries and ornamentals.

6. Garbutt, R.W. 1984. Foliage disease of western larch in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre, Pest Leaflet FPL 71.

   Reviews life history, recognition, damage, and control of *Meria laricis* and *Hypodermella laricis*.

7. Hubert, E.E. 1954. Needle cast disease of western larch. University of Idaho, Extension Service, Bulletin 215.

   Reviews damage by *Hypodermella laricis* and *Meria laricis* in Idaho. Control measures are not practicable in forest conditions. In European nurseries, *Meria laricis* has been controlled by spraying with lime sulphur mixture.

8. James, R.L. 1985. Meria needlecast of western larch seedlings at the USDA Forest Service Nursery, Coeur d'Alene, Idaho. USDA Forest Service, Northern Region, Forest Pest Management, Report 85-20.

   Needlecast caused by *Meria laricis* caused serious losses of 2-0 bareroot western larch during 1983. Cool, wet weather throughout the spring and summer of 1983 was ideal for disease buildup and spread. Control attempts with fungicides were largely unsuccessful because of the conducive weather conditions and high inoculum levels. The disease was also found on containerized larch, although serious damage was not evident. The 1984 bareroot crop had high levels of infection in the spring, but consistent fungicide treatments and warm, dry summer weather resulted in no detectable disease by fall.

9. Khabibullina, F.M. 1984. Systematic fungicides for protecting larch against needle cast. Lesnoe Khozyaistvo No. 4:47-49. (IN RUSSIAN)

   In a series of laboratory and nursery trials, a number of systematic fungicides were used to protect *Larix sibirica* seedlings from

needle cast caused by *Meria laricis:* Bavistin® (carbendazim), benomyl, BMC® (carbendazim), Daconil® (chlorothalonil), Derosal® (carbendazim), Olgin®, Topsin-M® (thiophanate), Fundazol®, colloidal S, Polikarbatsin®, zineb, and a cocktail of Bavistin®, benomyl, Derosal® plus zineb, and BMC® plus zineb. Nursery treatments were made as either five sprays per season at 15-day intervals, or three sprays per season at 30-day intervals; differences were not significant and therefore the three-spray regime is to be preferred. The best concentrations to use were 0.2 to 0.3 percent for Bavistin® and Olgin®, 0.3 to 0.4 percent for BMC®, 0.4 to 0.6 percent for Daconil®, and 0.3 to 0.5 percent for Derosal® and Topsin-M®. Strains of *M. laricis* developed resistance to benomyl. Combined preparations, and alternating applications (e.g. of Bavistin® and zineb) were particularly effective in preventing disease.

10. Lephant, C.D. and R.E. Denton. 1961. Needle discolorations of western larch. USDA Forest Pest Leaflet 61.

    Causes of larch needle discoloration are discussed: normal physiological processes, climatic abnormalities, noxious fumes, insects and the fungal diseases *Hypodermella laricis* and *Meria laricis*.

11. Maruyama, P.J. 1984. A new host and distribution record of a larch needle blight, *Meria laricis* Vuill., in Alberta. Canadian Plant Disease Survey 64(1):19.

    Meria laricis was identified in four specimens deposited at the Northern Forest Research Centre, this being the first record of the pathogen in Alberta and the first time it has been found on *Larix lyallii*.

12. McBride, R.P. and A.J. Hayes. 1979. Interactions of the leaf pathogen *Meria laricis* with nutrients and microorganisms of the larch phylloplane. Nova Hedwigia 31(1-2):507-517.

    Spores germinated better in sugar solution than in water. Amino acid solutions increased germination only in spores previously exposed to 0 degrees C for 48 hours. A similar

increase was noted when young and old or damaged larch leaves were introduced to the germination medium. Isolates including *Pseudomonas, Bacillus, Flavobacterium* and three yeasts reduced germination in a soil extract-yeast extract solution. Germination was also reduced when spores were applied to leaves of aseptically grown larch seedlings which had been previously treated with suspensions of *Pseudomonas* spp. or *B. mycoides* in nutrient broth or of *Sporobolomyces roseus* in water or sugar solution.

13. Myren, D.T. 1984. *Meria laricis* found on European larch in Ontario. Plant Disease 68(8):732.

    Needle cast of *Larix decidua* in a plantation of mixed conifers near Chatsworth was caused by *Meria laricis*, the first North American record on this larch species.

14. Peace, T.R. and C.H. Holmes. 1933. *Meria laricis:* the leaf cast disease of larch. Oxford Forestry Memoir 15:1-29.

    Discusses the fungus in nature, the fungus in culture, species and varieties attacked, the onset and spread of the disease, factors influencing the disease, other causes of damage, and control measures.

15. Phillips, D.H. 1963. Leaf cast of larch: *Meria laricis*. Forestry Commission (Great Britain), Leaflet 21.

    Describes the disease symptoms and control methods.

16. White, K.N. 1985. Field survival and growth of 1-0 and 2-0 western larch infected with *Meria laricis*. USDA Forest Service, Colville National Forest.

    One-year-old fall and spring sown and 2-year-old western larch bareroot seedlings infected with *Meria laricis* from the Wind River Nursery were outplanted on three sites in northeast Washington. After two growing seasons, the survival and growth of both 1-year-old stock types was significantly better

than the 2-year-old stock on all sites. The 1-year-old spring sown stock grew significantly better than the fall sown stock.

Lophodermium Needle Cast

(*Lophodermium* spp.)

We list 31 references for Lophodermium needle cast, the majority of these covering work in the northeastern United States and Europe on Scotch and red pines. There are only four Pacific Northwest references (9, 21, 28, 31). There are four articles which discuss the biology of *Lophodermium* (4, 5, 10, 13). Nine papers deal with chemical management (7, 8, 14, 15, 21, 23, 24, 25, 28), three with cultural management (3, 11, 29), one with biological control (12), and four with combined methods of chemical and cultural management (1, 2, 16, 20). Several articles are detection or impact reports (9, 17, 18, 26, 27). Four papers describe the biology and management of Lophodermium needle cast in general (6, 19, 22, 31). One reference is the proceedings of a symposium on *Lophodermium*, covering a variety of subjects (30).

1. Affeltranger, C.E. 1972. Incidence and control of Lophodermium needle cast on Scotch pine nursery seedlings. Plant Disease Reporter 56(5):457-460.

Maneb, applied in two spray schedules to 1-0 and 2-0 seedlings of a Spanish provenance of *Pinus sylvestris*, successfully controlled Lophodermium pinastri needle cast in a nursery in North Carolina, but seedlings treated with benomyl and untreated seedlings showed 60 percent or more infection. In an evaluation of untreated seedlings of four provenances of *P. sylvestris* (Bulgarian, Spanish, French, and Turkish), the Spanish provenance was the most severely damaged (80 percent infection); the other provenances were hardly affected (3 to 4 percent infection).

2. Carlson, L.W. 1972. Forest tree nursery disease control. IN: Western Forest Nursery Council and Intermountain Forest Nurserymen's Association, Proceedings of Joint Meeting, 1972, p. 111-114. Edited by H.W. Anderson, J.A. Bryan, R.P. Eide. Held August 8-10, 1972, Olympia, Washington.

Reviews chemical and cultural practices for control of the major disease problems: damping-off, gray mold, *Lophodermium*, and storage molds.

3. Dimitri, L. 1977. Influence of nutrition and application of fertilizers on the resistance of forest plants to fungal diseases. European Journal of Forest Pathology 7:177-186.

   A literature review which considers responses of fungal pathogens to soil nutrient conditions, and the influence of plant nutrient status of susceptibility of infection. In reference to *Lophodermium pinastri* on *Pinus sylvestris*, some researchers have found clear relationships between nutritional state and attack by *Lophodermium*. The attack on Scots pine on plots fertilized with N, P, K and Mg was only half of that on plants on plots without fertilization, but trace nutrients may also have some influence.

4. Diwani, S.A. and C.S. Millar. 1981. Biology of *Lophodermium seditiosum* in nurseries in north-east Scotland. IN: Recent research on conifer needle diseases. International Union of Forest Research Organizations, proceedings, edited by C.S. Millar. Held September 15-19, 1980, Sarajevo, Bosnia, Yugoslavia.

   'Spring Reddener' is the name often applied to needle browning associated with *L. seditiosum* in nurseries. Different workers have expressed different opinions regarding the causes of the rapid browning of needles associated with *Lophodermium* species. In this work, *L. seditiosum* has been found to infect needles in late summer. The fungus continues to colonize the needle by a slow growing hyphal complex until it has girdled and killed the distal part of the needle. Spring reddening of needles in association with *L. seditiosum* has been observed to be an interruption of the actual *L. seditiosum* symptoms, by abiotic factors. Brown needles killed by *L. seditiosum* or a combination of both *L. seditiosum* and abiotic agents are colonized by fast growing, normal hyphae of *L. seditiosum* which have originated from the mycelium complexes. Maturation of ascocarps started in mid-July and reached a peak in mid-

October.

5. Diwani, S.A. and C.S. Millar. 1986. Infection processes of three *Lophodermium* species on *Pinus sylvestris* L. IN: USDA Forest Service, General Technical Report WO-50, p.22-27. Recent research on conifer needle diseases, proceedings, edited by G.W. Peterson. Held October 14-18, 1984, Gulfport, Mississippi.

   Infection processes of *Lophodermium pinastri, L. conigenum,* and *L. seditiosum* have been studied. On current year needles of transplanted *Pinus sylvestris,* all three *Lophodermium* species penetrated the host directly through the cuticle and rarely through stomata. *L. seditiosum* was the only species found to be capable of colonizing green needles of the transplants. Colonization of tissues was by "hyphal complexes", which are thought to be important structures in latency exhibited by the *Lophodermia.*

6. Diwani, S.A. and C.S. Millar. 1986. Needle-cast disease in nurseries in north-east Scotland. Scottish Forestry 40(3):185-189.

   Outlines are given of plant sanitation, cultural and chemical methods for controlling *Lophodermium seditiosum* in Scots pine nurseries.

7. Iyer, J.G., S.H. Slayton and W.B. Wood. 1972. Maneb fungicide: its effect on soils and tree growth. Advancing Frontiers of Plant Sciences 29:223-246.

   Describes a study of soils and of *Pinus resinosa* seedlings at nurseries in Wisconsin, Minnesota, and Michigan where maneb was used for control of *Lophodermium pinastri.* Analyses of fungicide-treated and control soils failed to reveal any significant effect of weekly maneb applications at 12 lb/acre on the content of extractable Mn or on other fertility factors. Tissue analyses of nursery seedlings and transplants showed that the chemical composition of needles of treated *Pinus resinosa* closely resembled that of untreated *Pinus banksiana,* a species naturally resistant to *L. pinastri.* Experiments with 2-year-old *P. resinosa* seedlings grown in containers irrigated from below to maintain ca. 11, 24 and 40 percent soil moisture by volume

showed that as long as the difference between soil porosity and the volume of water did not exceed 15 percent, weekly applications of maneb at 24 lb/acre, and direct application of 400 lb/acre of $MnSO_4 \cdot H_2O$, produced no adverse changes in availability of nutrients, development of mycorrhizal short roots, or the morphology, growth rate and survival potential of the plants. Applications of either maneb or $MnSO_4 \cdot H_2O$, to soils with <7 percent air content by volume caused a marked deterioration in both the soil and the plants. In general, the results of the study suggest that when Maneb or other compounds containing Mn are used, artificial irrigation must be carefully controlled, especially on fine soils with a field moisture capacity >20 percent by volume.

8. Iyer, J.G. and S.A. Wilde. 1975. Maneb fungicide: its effect on nursery stock under different soil conditions. Mitteilungen der Bundesforschungsanstalt fur Forst- und Holzwirtschaft 108. *Lophodermium* in pines, proceedings of the 5th European Colloquium of Forest Pathologists, edited by B.R. Stephan and C.S. Millar. Held April 15-17, 1975.

   Discusses the adverse effect of the manganese content of maneb on the nursery stock on waterlogged soils, and its growth-promoting effect on dry soils, and the resistance-enhancing effect of increased manganese and aluminum contents in the foliage brought about by maneb spraying.

9. James, R.L. 1983. Needle tip dieback of ponderosa pine seedlings at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 83-11.

   Needle tip dieback of 2-0 ponderosa pine seedlings was investigated. Organisms associated with dieback symptoms were identified and infected trees were transplanted to determine disease effects on survival. The major fungus colonizing necrotic needles was *Lophodermium nitens*, a close associate of *L. pinastri*. The fungus often sporulated on the necrotic distal portion of needles. Necrotic tips were often broken during lifting and handling of seedlings. Most infected trees produced a new flush of foliage after transplanting and probably recov-

ered from the disease. Control of the disease is not warranted.

10. Lazarev. V. 1981. Bioecological characteristics of *Lophodermium* species on *Pinus sylvestris* in nurseries of Bosnia. IN: Recent research on conifer needle diseases. International Union of Forest Research Organisations, proceedings, edited by C.S. Millar. Held September 15-19, 1980, Sarjevo, Bosnia, Yugoslavia.

    A bioecological study of *Lophodermium pinastri* and *L. seditiosum* on primary and secondary needles of *Pinus sylvestris* in Bosnia confirms that the species differ in their morphology, ecology, life cycle and pathogenicity and suggests that morphological differences within each species depend upon the type of needle colonized. Study of the disease on primary needles is of great importance for nursery production. Most damage and death is caused by *L. seditiosum* which colonizes young physiologically active needles. *L. pinastri* is found only on older primary or secondary needles and never causes the death of seedlings or older plants in the nursery. A knowledge of the differences in the infection periods between the two species is important for effective chemical control, which can be achieved by protecting plants during the peak period of ascospore release for *L. seditiosum* from mid-August to October.

11. Merrill, W. and B.R. Kistler. 1978. Needlecast and weeds interact to cause branch mortality in Scots pine. Plant Disease Reporter 62(3):200-202.

    In two similar, adjacent plantations of Scots pine Christmas trees, one with and one without weed control, there was not significant difference in the average severity of needlecast caused by *Lophodermium pinastri.* In the plantation with weed control there was no mortality of lower branches. In contrast, in the plantation without weed control, branch mortality ranged from 13 percent in trees in needlecast severity class 1 to 41 percent in trees in needlecast severity class 5.

12. Minter, D.W. 1981. Possible biological control of *Lophodermium seditiosum* IN: Current research on conifer needle disease, p. 75-80. Proceedings of IUFRO Working Party, edited by C.S. Millar. Held September 15-19, 1980, Sarajevo, Yugoslavia.

    Needlecast disease of *Pinus sylvestris* caused by *Lophodermium seditiosum* in nurseries and young plantations is often associated with the presence of surrounding mature stands of pine. Fruit bodies on needles attached to fallen branches in the stands are identified as the inoculum source. *Lophodermium seditiosum* only colonizes such needles when the normal saprophytic occupant of this habitat, *L. conigenum*, is absent. The problem is thus generally restricted to stands which lack *L. conigenum*. Introducing *L. conigenum* to such stands to compete with and reduce inoculum levels of *L. seditiosum* is a potential biological control. A pilot experiment to be made on the island of Rhusm, West Scotland, will investigate this possibility.

13. Minter, D.W. and C.S. Millar. 1980. Ecology and biology of three *Lophodermium* species on secondary needles of *Pinus sylvestris*. European Journal of Forest Pathology 10(2/3):169-181.

    The ecology and biology of three *Lophodermium* species common on secondary needles of *Pinus sylvestris* were studied in northeastern Scotland using direct observation and cultural techniques. The species were each found to occupy a distinct habitat to the virtual exclusion of the others. *L. pinastri* was found on senesced needles in the litter; *L. conigenum* on needles killed prematurely (while still healthy and attached to their twig) when some other part of the tree was damaged, e.g. by root or stem fungi, ring barking, snow break, etc.; *L. seditiosum* was found on second-year needles on young trees in the nursery, associated with and appearing to cause the death of the plants. *L. pinastri* ascocarps matured and released spores between April and August, with a peak in May; *L. conigenum* ascocarps between October and June, with a peak between November and February; *L. seditiosum* ascocarps between August and April, with a peak between October and December. Reports of the sporulation period of *Lophodermium* on pines are examined and found to vary greatly, suggesting that different workers were recording the sporulation of different species.

Published recommended spraying times against ascospores of the pathogenic *Lophodermium* however do not vary, but are consistent with the sporulation period of *L. seditiosum.*

14. Nicholls, T.H. 1970. Control of *Lophodermium pinastri* on red and Scotch pines in Lake States forest nurseries. Proceedings, Northeastern Area Nurserymen's Conference 1970, pp. 6-14.

    An outbreak of the needlecast fungus, *Lophodermium pinastri,* killed or caused severe damage to several million red pine (*Pinus resinosa* Ait.) and Scotch pine (*P. sylvestris* L.) seedlings in 14 nurseries in Michigan, Minnesota, and Wisconsin from 1966 to 1969. The outbreak was brought under control with the use of the fungicide maneb.

15. Nicholls, T.H. 1973. Fungicide control of *Lophodermium pinastri* on red pine nursery seedlings. Plant Disease Reporter 57(3):263-266.

    Reports a study of *Pinus resinosa* seedlings infected with *Lophodermium pinastri* in a nursery in Wisconsin between 1970 and 1972. Nineteen fungicide treatments were evaluated in tests with five fungicides (benomyl, ziram, chlorothalonil, chlorothalonil + cycloheximide, and maneb) that were applied, in a range of concentrations (0.1 to 1.0 percent), to test plots from one to three times during the growing season. Plots were sprayed between July and September to coincide with the period of maximum spore release. Two or three applications at low concentrations (0.1 to 0.3 percent) of all the fungicides except ziram gave effective control of *L. pinastri;* ziram was ineffective.

16. Nicholls, T.H. 1975. Control of *Lophodermium pinastri* on *Pinus resinosa* and P. sylvestris in nurseries and Christmas tree plantations in the United States. Mitteilungen der Bundesforschungsanstalt fur Forst- und Holzwirtschaft 108:147-153. *Lophodermium* in pines, proceedings of the 5th European Colloquium of Forest Pathologists, edited by B.R. Stephan and C.S. Millar. Held April 15-17, 1975.

    Mention is made that short-needled Spanish and French Green

varieties of *P. sylvestris* are susceptible, while long-needled varieties such as Scottish Highland and Austrian Hills are more resistant.

17. Nicholls, T.H. 1975. Lophodermium needlecast of conifer nursery seedlings. American Phytopathological Society, Proceedings 2:30.

    Two strains of *Lophodermium pinastri* are reported on *Pinus resinosa* and *Pinus sylvestris* in North America, one being saprophytic on old or dying needles and the other parasitic on healthy needles.

18. Nicholls, T.H. and D.D. Skilling. 1970. *Lophodermium pinastri* outbreak in Lake States forest nurseries. Plant Disease Reporter 54(9):731-733.

    Short-needled *Pinus sylvestris* varieties were highly susceptible to infection, but long-needled varieties appeared to be resistant. *Pinus densiflora* was seriously and *P. banksiana* lightly infected; *P. strobus*, *Picea mariana*, and *Picea glauca* were not infected. Trees of red and Scotch pine in windbreaks appear to be a major source of infection. Nursery losses from this disease could be high. Older trees suffer little damage other than unsightliness, but a Scotch pine Christmas tree plantation was rendered unsaleable. It is suggested that a more virulent form of the fungus may now be present in North America.

19. Nicholls, T.H. and D.D. Skilling. 1972. *Lophodermium pinastri* needlecast disease of Scotch pine Christmas trees. American Christmas Tree Journal 16(2):11-13.

    Describes, and illustrates with color photos, attack by *Lophodermium pinastri* on nursery seedlings and older Christmas trees of *Pinus sylvestris* in the U.S., and briefly discusses the problem of control. Repeated sprayings with maneb every 2 weeks August through October is effective but costly. An effective and economical fungicide has yet to be found.

20. Nicholls, T.H. and D.D. Skilling. 1974. Control of Lophodermium needlecast disease in nurseries and Christmas tree plantations. USDA Forest Service, North Central Forest Experiment Station, Research Paper NC-110.

Fungicide and cultural control recommendations are given for the disease, which has recently caused serious losses in red pine and Scots pine in the U.S. and Canada. In 1966 and 1967 it killed or severely damaged millions of seedlings of these very susceptible species (especially the short-needled *Pinus sylvestris* varieties) in several Minnesota, Wisconsin, and Michigan nurseries. Symptoms and life history of the pathogen are described and the need for its early detection is emphasized. Fungicide spray schedules are based on the fact that the major spore dispersal period is August through October, September being the key month for spore release and infection. The amounts of maneb or chlorothalonil needed for control are: hydraulic sprayer, 2.5 lb/100 gal (1 acre); roto mistblower, 6 lb/100 gal (2-1/2 acres); low volume mistblower, 12.5 lb/100 gal (5 acres); and fixed wing aircraft, 2.5 lb/5 to 10 gal (1 acre).

21. Ormrod, D.J. 1976. Control of Lophodermium needlecast of Scot's pine Christmas trees in British Columbia. Canadian Plant Disease Survey 56:69-72.

Lophodermium pinastri on *Pinus sylvestris* was first recognized as a problem on Christmas trees in North American in 1966 and caused serious losses in British Columbia in 1970. In an experiment begun in 1971, various fungicides and spray schedules were applied to trees in the third, fourth, and fifth year of growth. Mancozeb, chlorothalonil, and benomyl were the most effective. The minimum acceptable spray schedule requires three applications between late July and mid-September each year.

22. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Lophodermium needle cast.

23. Powell, C.C. and C. Leben. 1973. Epidemiology and control of Lophodermium needlecast of Scotch pine in Ohio. Plant Disease Reporter 57:515-517.

Of six fungicides tested for control of *Lophodermium pinastri* on *Pinus sylvestris,* 80 percent maneb at 2 lb/100 gal water was most effective when applied monthly from June through October. In two seasons of study, fruiting body development and spore dissemination occurred in late August and throughout September. Analysis of weather data suggests that such dissemination is not strictly dependent on periods of wet weather. Thus, a mid-August and mid-September maneb spray for practical control of needlecast in Ohio Christmas tree plantations is recommended.

24. Sakuyama, T. 1981. Lophodermium needle cast of Japanese red pine seedlings in northern Honshu, Japan. International Union of Forest Research Organization, 17th World Congress, 2:619.

Serious damage by *Lophodermium pinastri* was observed on Japanese red pine at many forest nurseries in Iwate Prefecture, Japan. During 1972-74, several million 2-0 seedlings were killed. Five fungicides were tested for control of the disease. Maneb gave satisfactory control when applied at 2-week intervals during July through September.

25. Skilling, D.D. 1974. Control of Lophodermium needlecast in Scotch pine Christmas tree plantations. Plant Disease Reporter 58:853-856.

Describes the laboratory and field trials in Indiana and Michigan during 1971 and 1972 that led to the use of chlorothalonil and maneb for control of *Lophodermium pinstri* in plantations of *Pinus sylvestris.*

26. Skilling, D.D. and T.H. Nicholls. 1975. The development of *Lophodermium pinastri* in conifer nurseries and plantations in North America. European Journal of Forest Pathology 5(4):193-197.

A sudden outbreak of the disease occurred in 1966 on red pine and Scotch pine. Dispersal of infected nursery stock throughout North American has created a serious needlecast problem in Scotch pine Christmas tree plantations. Two biotypes of the fungus are present. The pathogenic strain may be a recent introduction. Maneb and chlorothalonil are being used for control.

27. Spaulding, P. 1935. *Lophodermium pinastri* causing leafcast of Norway pine in nurseries. USDA Forest Service, Northeastern Forest Experiment Station, Technical Note 18.

Describes and gives control measures for a destructive leaf cast disease recently noticed on Norway pine in nursery seed and transplant beds.

28. Staley, J., G. Raymond, G. Harvey, R. Deskins, A. Davison, and K. Russell. 1981. Control of Lophodermium needlecast in Pacific Northwestern Scotch pine. Northwest Lookout, May 1981, p.36-40.

In the Pacific Northwest, three *Lophodermium* species cause foliar damage to Scotch pine Christmas trees, and are also present, with or without damage, in certain Scotch pine nurseries. Spore dispersal periods of the three fungi overlap and in the mild, maritime climate, spore dispersal periods extend over 9 months. Economic chemical control can be obtained, but requires many more spray coverages than are needed in a continental climatic regime. Of several chemicals tested, maneb was most cost effective.

29. Stephan, B.R. and D. Krusche. 1986. Genetic variation of resistance to Lophodermium needle cast in Scots pine progenies of intra-provenance and interprovenance crossings. IN: USDA Forest Service, General Technical Report WO-50, p.28-34. Recent research on conifer needle diseases, proceedings, edited by G.W. Peterson. Held October 14-18, 1984, Gulfport, Mississippi.

    The Lophodermium needle cast resistance of 96 families of crosses between phenotypically selected Scots pine trees (*Pinus sylvestris*) of a Mazurian and an Alpine provenance was investigated at two locations in northern Germany. The fungal attack was evaluated on 9-year-old crossings and showed highly significant genetic variation between and within the intra-provenance and interprovenance crossings. A quantitative genetic analysis of the data showed strong additive genetic variation and a relatively high heritability of resistance. Resistance to *Lophodermium seditiosum* might be incorporated successfully into breeding programs in Scots pine.

30. Stephan, B.R. and C.S. Millar, compilers. 1975. *Lophodermium* on pines: proceedings of the 5th European colloquium for forest pathologists, section III - VI. Mitteilungen der Bundesanstalt fur Forst- und Holzwirtschaft 108:97-201. Held April 15-17, 1975.

    Two papers specific to nurseries are noted separately. Titles of remaining papers: An attempt to determine the characters that differentiate provenances of Scots pine in resistance to *Lophodermium pinastri; Lophodermium pinastri* - an outline of the problem in Sweden; Some aspects of field trials with pines to estimate resistance to *Lophodermium pinastri;* New control methods of *Lophodermium pinastri;* Cultivation of *Lophodermium pinastri* in vitro; Plantifog 160M®, oily fungicide for *Lophodermium* control; Experiments with chemical control of Lophodermium needle-cast; Prophylactic control of pine needlecast in the tree nursery area of Pinneberg; The outbreak and biology of *Lophodermium pinastri* on *Pinus resinosa* and *P. sylvestri* in North America; The status of *Lophodermium* research in Canada; Research on *Lophodermium pinastri* in Hungary.

31. Ziller, W.G. and R.S. Hunt. 1972. *Lophodermium pinastri* needle cast of pines in nurseries and plantations. Forest Insect and Disease Survey, Canada, Pest Leaflet No. 52.

Briefly reviews the hosts, distribution and life history of this fungus, which causes serious defoliation on *Pinus sylvestris* Christmas trees in the lower Fraser Valley, British Columbia, and elsewhere, and discusses control measures.

Lower Stem Canker

(*Fusarium roseum, Phoma eupyrena*)

We found eight references on lower stem canker. All work on this disease to date has been done in the Pacific Northwest, primarily on Douglas-fir. Since this is a recently recognized disease, there are no reports earlier than 1984. Five articles cover the biology of the complex of organisms which cause the disease (1, 4, 5, 6, 7); one paper deals with impact and detection (2); one deals with chemical control (3); and one is a general paper on management techniques (8).

1. Anonymous. 1985. Nursery pathology research project. Oregon State University Forest Research Laboratory Nursery Technology Cooperative, Annual Report 1984-85, p.11-12.

After two years of detailed disease monitoring, some aspects of the top blight disease complex of Douglas-fir have been clarified. Pathogens involved include *Fusarium oxysporum* on hypocotyls, *Phoma eupyrena*, and *Fusarium roseum* on the upper stem, and *P. eupyrena, F. roseum*, and *Phoma pomorum* on the lower stem during the first year, and *Phomopsis* near the base of new growth in the second year. All fungi involved are soil inhabitants, spread by rain and soil movement; therefore soil management will be the key part of any successful control.

2. Bega, R.V. 1984. Factors contributing to a severe root-aerial disease complex at a large conifer nursery. IN: Western International Forest Disease Work Conference, Proceedings 32:67-68.

The Forest Service Humboldt Nursery is suffering large losses of *Pseudotsuga menziesii, Abies magnifica, A. concolor*, and *P.*

ponderosa seedlings. Isolation of organisms was attempted from diseased seedlings which were stunted, somewhat chlorotic, with a severely restricted root systems, numerous rootlet lesions and some stem and needle lesions. The most consistently isolated organisms were *Fusarium oxysporum, Pythium,* and *Phoma.*

3. Cooley, S.J. and A. Kanaskie. 1986. Evaluation of seven fungicides to control canker diseases of bare-root Douglas-fir in Pacific Northwest nurseries. USDA Forest Service, Pacific Northwest Region, Report R6-86-14.

The fungicides Benlate®, Captan®, Chipco 26019®, Daconil 2787®, Difolatan®, Mertect®, and Zyban® were applied periodically at five nurseries in Oregon and Washington for control of Douglas-fir canker diseases. Hypocotyl rot, resulting from ground-line infections by *Fusarium oxysporum,* was reduced by Benlate® at two nurseries; the other fungicides were less effective. Upper stem infections resulting in top mortality were caused primarily by *Phoma* spp. and *Fusarium* spp. and occurred in October and early November. In two nurseries that experience relatively high levels of upper stem canker, all fungicides significantly reduced cankering. Lower stem cankers, seen in spring and summer of the second year, were not controlled by fungicides if cankers were at groundline; good control was achieved with Daconil® and Difolatan® when cankers were higher on the stem and not covered with a soil collar. Cankers caused by *Botrytis* were prevalent in the summer and fall of the second year at one nursery; all fungicides gave effective control, although Daconil® and Difolatan® were superior.

4. Hamm, P.B. and E.M. Hansen. 1987. Stem canker disease of Douglas-fir in nurseries. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.106-108. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

Diseases that kill above-ground portions of Douglas-fir formerly called "top blight" are listed. Disease recognition, time of infection, infection site, and causal agents are described.

5. Hamm, P.B., E.M. Hansen, and A.M. Kanaskie. 1985. Symptomology of the "top blight" diseases of Douglas-fir bare-root seedlings in nurseries in the Pacific Northwest. Phytopathology 75(11):1367.

Top blight, an ill-defined syndrome, describes at least three distinct periods of mortality. In mid-summer, when seedlings are 3 months old, a hypocotyl rot occurs at or just above the soil line. Seedling tops quickly turn brown while roots are not discolored. *Fusarium oxysporum* is isolated. From September through November, cankers, centered on bark fissures, lateral or terminal shoots, or needle scars, appear between the midstem and seedling apex. *F. roseum* and *Phoma eupyrena* are recovered. A third type of symptom, December through May, is associated with soil collars built up by irrigation and splashing rain. Seedlings are girdled at or above the cotyledon scar, with top symptoms sometimes not evident until new growth suddenly wilts during the spring. *F. roseum* and *P. eupyrena* are most frequently isolated from diseased seedlings.

6. Hansen, E.M. and P.B. Hamm. 1988. Canker diseases of Douglas-fir fir seedlings in Oregon and Washington bareroot nurseries. Canadian Journal of Forestry Research (In Press).

Canker diseases in northwestern forest nurseries have been referred to collectively as "top blight." To distinguish among the various symptoms and their associated fungi, systematic observations of and isolations from *Pseudotsuga menziesii* seedlings through two crop cycles in four northwestern nurseries were made, and suspect fungi were subjected to pathogenicity testing. Five diseases were distinguished. Hypocotyl rot, caused by *Fusarium oxysporum*, kills seedlings during their first growing season. Upper stem canker, caused by *Phoma eupyrena* and *Fusarium roseum*, girdles seedlings in mid-stem in the fall of their first year. Lower stem canker, also caused by *P. eupyrena* and *F. roseum*, kills seedlings in the winter or early spring of their second year and is associated with soil collars built up by splashing water. *Botrytis* and *Phomopsis* cankers occasionally kill new shoots during the second year. Not all diseases are damaging every year or in every nursery.

7. James, R.L. and P.B. Hamm. 1985. Chlamydospore-producing species of *Phoma* from conifer seedlings in Pacific Northwest forest tree nurseries. Montana Academy of Science, Proceedings 45:26-36.

   Three species of *Phoma* that produce chlamydospores in culture are frequently isolated from diseased conifer seedlings from several Pacific Northwest nurseries. These include *P. eupyrena*, *P. glomerata*, and *P. pomorum*. Major differentiating characteristics of these species include abundance and morphology of chlamydospores, growth habit in culture, conidial exudate color and conidial pigmentation, shape, septation, and size. Cultural characteristics of these three *Phoma* species and a brief description of their habit in nature are discussed.

8. Kanaskie, A. 1987. Management of the top blight disease complex. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.115-121. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

   The "top blight disease complex" refers to five separate but related diseases affecting above-ground portions of bareroot Douglas-fir seedlings. Disease losses can be reduced by altering cultural practices or applying fungicides. The following paper provides practical approaches and techniques for reducing losses from top blight.

Phoma Tip Blight

(*Phoma* spp.)

We found 11 references on Phoma tip blight. All work on this disease has been done in the west including Oregon, northern California, Idaho, and Montana. A variety of tree species are hosts to *Phoma*, including Douglas-fir, red fir, Englemann spruce, ponderosa, lodgepole, Jeffrey and Scotch pines. The majority of references are detection or impact reports (2, 3, 4, 5, 6, 7, 11). The remainder deal with the biology of the organism (8, 10) or some aspect of disease management (1, 9).

1. Freeman, W.L., Jr. 1984. Results of 1983-1984 trials for control of Phoma blight of red fir at the Humboldt Nursery. USDA Forest Service, Pacific Southwest Region, Report 84-39.

Previous tests of fungicides for the control of Phoma blight had been ineffective, but observations indicated that prevention of soil cone formation would lessen the impact of the disease. This trial, using three fungicides in combination with a redwood mulch or shade frames to decrease rain splash, was conducted in 1983-84. Results showed that both the mulch and the lath cover significantly reduced the incidence of Phoma blight, but none of the fungicide treatments significantly reduced the number of seedlings killed, either with or without the mulch or cover.

2. James, R.L. 1980. Engelmann spruce needle and twig blight at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Forest Insect and Disease Management, Report 80-21.

Needle and twig blight of *Picea engelmannii* was investigated to determine probable causes and formulate recommendations for reducing future losses. The two major fungal genera consistently isolated from symptomatic seedlings were *Phoma* and *Botrytis*. Diseases caused by *Phoma* and *Botrytis* can usually be effectively controlled with fungicides. Chlorothalonil is registered for *Phoma* and is most effective when applied at 2-week intervals during cool, wet weather. Fungicide application has traditionally been used to control Botrytis blight; however, development of tolerance to certain chemicals by various strains of the fungus have been reported. No fungicides are currently registered for *Botrytis* at the Coeur d'Alene Nursery.

3. James, R.L. 1983. Fungi associated with tip dieback of ponderosa pine seedlings at the Clifty View Nursery, Bonners Ferry, Idaho. USDA Forest Service, Northern Region.

1-0 ponderosa pine seedlings were examined to determine possible causes of tip dieback and necrosis. *Sirococcus strobilinus* was isolated from 10 percent of the seedlings received. *Phoma eupyrena* and *P. herbarum* were commonly found sporulating on and were isolated from necrotic tissues both at the

tips and at the base of affected seedlings. *Diplodia pinea* was infrequently isolated from tip blighted seedlings. *Epicoccum nigrum* was commonly isolated from necrotic stem and needle tissues. In addition, four isolates of *Sirococcus strobilinus* were screened for possible tolerance to chlorothalonil. The isolates examined were not very tolerant; however, sustained heavy doses of the fungicide may select for more tolerant strains of the fungus.

4. James, R.L. 1984. Tip blight of ponderosa pine seedlings at the Fantasy Farms Nursery, Peck, Idaho. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 84-3.

   An evaluation was conducted to identify fungi associated with tip blight and dieback of ponderosa pine seedlings. The disease was most prevalent in 1-0 pine seedbeds, where affected seedlings were scattered throughout beds rather than being concentrated in groups or restricted to certain areas. *Diplodia pinea* was identified as the major source of sporulation on necrotic tissues; *Phoma eupyrena* was also isolated.

5. James, R.L. 1987. Phoma tip blight of bareroot lodgepole pine seedlings, Champion Timberlands Nursery, Plains, Montana. USDA Forest Service, Northern Region.

   Tip blight was located on several *Pinus contorta* seedlings in the spring of their second growing season. Microscopic examination revealed that they were from the genus *Phoma*. *Phoma* are common soil inhabitants and are usually controlled by fumigation of nursery soil prior to sowing. Disease incidence is usually not severe enough in Rocky Mountain nurseries to warrant specific control measures.

6. James, R.L. 1987. Tip blight of Scots pine seedlings - Montana State Nursery, Missoula. USDA Forest Service, Northern Region.

   Tip blight of *Pinus sylvestris* was recently discovered in 2-0 seedbeds at the Montana State Nursery. Two species of *Fusarium* (*F. oxysporum* and *F. acuminatum)* and *Phoma pomorum* were

commonly found. Recent changes at the nursery have stressed soil treatment with fumigants, which should reduce future losses from tip blight, as well as damping-off and root diseases.

7. James, R.L. and S.J. Cooley. 1987. Tip blight of bareroot ponderosa and lodgepole pine seedlings - USDA Forest Service Nursery, Bend, Oregon. USDA Forest Service, Northern Region.

   Diseased seedlings were collected during the summer of 1987 for analysis of fungi associated with tip dieback symptoms. Five genera of fungi were consistently found sporulating on necrotic stem tissues. These included *Phoma, Fuarium, Alternaria, Botrytis,* and *Epicoccum.* It was felt that *Phoma* and *Fusarium* were most likely responsible for tip blight symptoms, so the isolates were further identified to species. Two species of *Phoma, P. eupyrena* and *P. pomorum,* and two species of *Fusarium, F. oxysporum* and *F. acuminatum,* were isolated. *Phoma* and *Fusarium* spp. were likely soil inhabitants which were present in sufficient numbers to cause disease when environmental conditions were conducive to infection.

8. James, R.L. and P.B. Hamm. 1985. Chlamydospore-producing species of *Phoma* from conifer seedlings in Pacific Northwest forest tree nurseries. Montana Academy of Science, Proceedings, 45:26-36.

   Three species of *Phoma* that produce chlamydospores in culture are frequently isolated from diseased conifer seedlings from several Pacific Northwest nurseries. These include *P. eupyrena, P. glomerata,* and *P. pomorum.* Major differentiating characteristics of these species include abundance and morphology of chlamydospores, growth habit in culture, conidial exudate color and conidial pigmentation, shape, septation, and size. Cultural characteristics of these three *Phoma* species and a brief description of their habit in nature are discussed.

9. Kliejunas, J. 1983. Fungicide trials for control of *Phoma* and *Sirococcus* at the Humboldt Nursery. IN: Western International Forest Disease Work Conference, 31:50-53.

   Ten fungicides to control Phoma blight of red fir and five fungicides to control Sirococcus tip blight of Jeffrey pine were evaluated at the Humboldt Nursery. Fungicides were applied at approximately one month intervals from September 1982 to May or June 1983. Efficacy was determined by comparing the percentage of red fir killed or Jeffrey pine cankered in each treated plot with adjacent untreated plots. None of the fungicides tested effectively controlled Phoma blight of red fir. Three fungicide — chlorothalonil, ectaconazole, and triadimefon — were efficacious in controlling Sirococcus tip blight of Jeffrey pine; vinclozolin and iprodione were not.

10. Kliejunas, J.T., J.R. Allison, A.H. McCain, and R.S. Smith, Jr. 1985. Phoma blight of fir and Douglas-fir seedlings in a California nursery. Plant Disease 69(9):773-775.

    Phoma eupyrena was consistently associated with needle cast and blight of red fir and Douglas-fir seedlings at a nursery near the coast of northern California. Symptoms typically developed during the dormant period between the first and second growing season. Heavy rains and soil splash resulted in the buildup of soil cones around the stem and lower crown, followed by infection of lower needles or buds by the soilborne fungus. Inoculations of greenhouse-grown seedlings with *Phoma eupyrena* in soil resulted in symptoms identical to those observed in the field. Protective fungicides tested on red fir gave little or no control. The addition of a redwood mulch and the use of a shade cover reduced soil splash, soil cone formation and disease incidence.

11. Srago, M. 1978. Nursery disease problems - Phoma blight. IN: Western Forest Nursery Council and Intermountain Nurseryman's Association, Conference and Workshop Proceedings, 1978, p.B138, edited by R.W. Gustafson. Held October 1978, Eureka, California.

    In 1979 and 1975 there were major losses of 1-0 Douglas-fir at the Humboldt Nursery in McKinleyville, California. The

fungus most commonly isolated from the needles and stems of these declining trees has been a *Phoma* species. Although pathogenicity tests have not been conducted at this time, evidence suggests that *Phoma* spp. is the probably cause of the disease.

Phomopsis Canker

(*Phomopsis* spp.)

We have listed 15 references on Phomopsis canker. It occurs primarily on Douglas-fir in both the nursery and on young trees in the field (3, 5, 6, 9). Twelve of the 15 references are from the Pacific Northwest. Six references deal with the biology of *Phomopsis* (1, 5, 7, 8, 9, 14) and two are detection and impact reports (2, 3). There are three reports of chemical trials (4, 11, 12), one article discussing management via cultural means (15), and one which discusses use of both chemical and cultural methods (10). Two papers cover the biology and management of the disease in a general fashion (6, 13).

1. Anonymous. 1985. Nursery pathology research project. Oregon State University Forest Research Laboratory, Nursery Technology Cooperative, Annual Report 1984-85, p.11-12.

After two years of detailed disease monitoring, some aspects of the top blight disease complex of Douglas-fir have been clarified. Pathogens involved include *Fusarium oxysporum* on hypocotyls, *Phoma eupyrena* and *Fusarium roseum* on the upper stem and *P. eupyrena, F. roseum,* and *Phoma pomorum* on the lower stem during the first year, and *Phomopsis* near the base of new growth in the second year. All fungi involved are soil inhabitants, spread by rain and soil movement; therefore, soil management will be a key part of any successful control.

2. Bega, R.V. 1978. *Phomopsis lokoyae* outbreak in a California forest nursery. Plant Disease Reporter 62(7):567-569.

The fungus caused a major epidemic in Douglas-fir in the Forest Service Humboldt Nursery in McKinleyville, California, the first report of such an outbreak in a California nursery. The damage caused a drastic reduction in inventory and shipping estimates for the 1976 planting season.

3. Boyce, J.S. 1933. A canker of Douglas-fir associated with *Phomopsis lokoyae*. Journal of Forestry 31:664-672.

   A canker disease of young Douglas-fir became epidemic in the northern Coast Range of California during 1930 because of a combination of climatic conditions unfavorable to the host and favorable to the disease. The epidemic had subsided by 1931. It will recur again when similar conditions arise. The disease resembles a canker disease of Douglas-fir in Europe, but it is apparently indigenous, or at least behaving as an indigenous disease. The damage resulting was negligible, most of the dying of Douglas-fir and other species resulting from the protracted drought of 1929.

4. Cooley, S.J. and A. Kanaskie. 1986. Evaluation of seven fungicides to control canker diseases of bare-root Douglas-fir in Pacific Northwest nursery. USDA Forest Service, Pacific Northwest Region, Report R6-86-14.

   The fungicides Benlate®, Captan®, Chipco 26019®, Daconil 2787®, Difolatan®, Mertect®, and Zyban® were applied periodically at five nurseries in Oregon and Washington for control of Douglas-fir canker diseases. Hypocotyl rot, resulting from ground-line infections by *Fusarium oxysporum*, was reduced by Benlate® at two nurseries; the other fungicides were less effective. Upper stem infections resulting in top mortality were caused primarily by *Phoma* spp. and *Fusarium* spp. and occurred in October and early November. In two nurseries that experience relatively high levels of upper stem canker, all fungicides significantly reduced cankering. Lower stem cankers, seen in spring and summer of the second year, were not controlled by fungicides if cankers were at groundline; good control was achieved with Daconil® and Diolatan® when cankers were higher on the stem and not covered with a soil collar. Cankers caused by *Botrytis* were prevalent in the summer and fall of the second year at one nursery; all fungicides gave effective control, although Daconil® and Difolatan® were superior.

5. Funk, A. 1968. *Diaporthe lokoyae* n. sp., the perfect state of *Phomopsis lokoyae*. Canadian Journal of Botany 46:601-603.

A new species of *Diaporthe*, for which the name *D. lokoyae* Funk is proposed, is described on the host Douglas-fir and in culture. This *Diaporthe* is shown to be the ascigerous state of *Phomopsis lokoyae*. An outbreak of dieback in Douglas-fir associated with this *Diaporthe* is described and discussed; a single occurrence on western hemlock is reported.

6. Funk, A. 1973. Phomopsis (Diaporthe) canker of Douglas-fir in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre, Pest Leaflet 60.

Phomopsis (Diaporthe) canker of *Pseudotsuga menziesii* is caused by the fungus *Diaporthe lokoyae*. It is referred to as Phomopsis canker because the asexual stage of the fungus, *Phomopsis lokoyae*, was found much earlier than the *Diaporthe* or sexual stage. The disease causes stem cankers, leader and branch dieback in trees from seedling to pole size. Host, distribution, life history, recognition, damage, and control are discussed.

7. Hamm, P.B. and E.M. Hansen. 1987. Stem canker disease of Douglas-fir in nurseries. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.106-108. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

Diseases that kill above ground portions of Douglas-fir, formerly called "top blight", are listed. Disease recognition, time of infection, infection site, and causal agents are described.

8. Hansen, E.M. and P.B. Hamm. 1988. Canker diseases of Douglas-fir seedlings in Oregon and Washington bareroot nurseries. Canadian Journal of Forestry Research (In Press).

Canker disease in northwestern forest nurseries have been referred to collectively as "top blight." To distinguish among

the various symptoms and their associated fungi, we made systematic observations of and isolations from *Pseudotsuga menziesii* seedlings through two crop cycles in four northwestern nurseries, and suspect fungi were subjected to pathogenicity testing. Five diseases were distinguished. Hypocotyl rot, caused by *Fusarium oxysporum*, kills seedlings during their first growing season. Upper stem canker, caused by *Phoma eupyrena* and *Fusarium roseum*, girdles seedlings in mid-stem in the fall of their first year. Lower stem canker, also caused by *P. eupyrena* and *F. roseum*, kills seedlings in the winter or early spring of their second year and is associated with soil collars built up by splashing water. *Botrytis* and *Phomopsis* cankers occasionally kill new shoots during the second year. Not all diseases are damaging every year or in every nursery.

9. Hood, I.A. and C.J. Sandberg. 1985. Some major fungi of conifers (*Phomopsis pseudotsugae, P. juniperovora*, and *Rhizosphaera kalkhoffii*). New Zealand Forest Research Institute, Forest Pathology in New Zealand No. 13.

   Phomopsis pseudotsugae (*Potebniamyces coniferarum*) causes shoot dieback, stem girdling and cankering in young trees following frost injury or wounding, and occurs on *Pinus radiata, P. muricata, P. canariensis*, and *Pseudotsuga menziesii. Phomopsis juniperovora* causes shoot death or cankering of nursery seedlings of *Chamaecyparis lawsoniana, Cupressus lusitanica, C. macrocarpa*, and *Larix decidua. Rhizosphaera kalkoffii* colonizes needle tissues killed from other causes and occurs in *Abies grandis, Picea abies, P. sitchensis, Pinus jeffreyi, Pseudotsuga menziesii*, and *Sequoia sempervirens*. The symptoms, disease development, distribution, economic importance and control of these fungi are discussed.

10. Kanaskie, A. 1987. Management of the top blight disease complex. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.115-121. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

The "top blight disease complex" refers to five separate but related diseases affecting above-ground portions of bareroot Douglas-fir seedlings. Disease losses can be reduced by altering cultural practices or applying fungicides. The following paper provides practical approaches and techniques for reducing losses from top blight.

11. Kliejunas, J. 1986. Evaluation of fungicides for control of Phomopsis canker of Douglas-fir at Humboldt Nursery. USDA Forest Service, Pacific Southwest Region, Forest Pest Management Report 86-18.

Sixteen fungicides were evaluated in vitro and five were evaluated in field trials for control of Phomopsis canker of 2-0 *Pseudotsuga menziesii* at Humboldt Nursery. Most of the fungicides inhibited or reduced spore germination compared to no treatment. Six fungicides prevented (benomyl, imazalil, prochloraz, diniconazole) or reduced (chlorothalonil, mancozeb) mycelial growth at 1 ppm. Five fungicides (diniconazole, chlorothalonil, benomyl, mancazb,and imazalil) tested in the field gave significantly better control than no treatment. Benomyl, the fungicide registered for *Phomopsis* control, was more efficacious than mancozeb and imazalil, but was not as effective as diniconazole or chlorothalonil.

12. Kliejunas, J. 1988. Fungicide trials for control of Phomopsis canker of Douglas-fir at a northern California nursery. Tree Planters' Notes 39(2):26-29.

Based on in vitro evaluation of sixteen fungicides, five were field-tested for efficacy against Phomopsis canker of 2-0 *Pseudotsuga menziesii.* All gave significantly better control than no treatment. Benomyl, the fungicide registered for *Phomopsis* control, was more efficacious than mancozeb and imazalil, but was not as effective as diniconazole or chlorothalonil.

13. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Phomopsis canker.

14. Sanderson, P.G. and G.L. Worf. 1986. Phomopsis and Sirococcus shoot blights of Colorado blue spruce in Wisconsin. Plant Disease 70(12):1159.

    Needle necrosis and tip blight on Colorado blue spruce in a Wisconsin nursery were caused by *Phomopsis occulta*. Initial symptoms were chlorotic flecks on the basal half of needles near the shoot tips, followed by small stem cankers and often accompanied by resinous exudates. Symptom severity was greatest when inoculated plants were maintained at a warm temperature (25 degrees C) and high RH (79 to 95 percent). *Picea pungens, P. obovata, P. glauca,* P. *abies, Abies balsamea,* and *A. concolor* were inoculated with *Phomopsis occulta*. Only spruce species, particularly *Picea pungens,* showed symptoms. *Sirococcus strobilinus* was isolated from a 15-year-old Colorado blue spruce showing symptoms similar to those caused by *P. occulta.* Pathogenicity of *S. strobilinus* was confirmed for the first time on this host in Wisconsin.

15. Sutherland, J.R. and R.L. Anderson. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. IN: North American Forest Tree Nursery Soils Workshop, Proceedings, p.182-190. Held July 28-August 1, 1980.

    Soil conditions play a major role in preventing or causing devastating losses from many nursery disease and insect problems. This paper reviews the relationships between several soil factors, cultural practices, and certain disease and insect problems.

Phytophthora Root Rot
(*Phytophthora* spp.)

We have listed 34 references on Phytophthora root rot in the bibliography. The majority of these deal with Phytophthora root rot of Douglas-fir and other Pacific Northwest species, although we have

also included a number of articles about Phytophthora root rot on Fraser fir in North Carolina nurseries. Twenty-one of the references discuss the biology, symptomology, spread, or pathogenicity of various *Phytophthora* species; two of these (7, 14) report the relative susceptibility of Pacific Northwest conifer species to *Phytophthora* species found in Pacific Northwest nurseries and two (9, 34) are general references on *Phytophthora*. Six references (3, 4, 10, 12, 19, 24) deal specifically with chemical control of the disease. An additional five (5, 6, 8, 26, 33) discuss Phytophthora root rot management (including both cultural and chemical strategies) in more general terms. Three references (1, 10, 11) report nursery and outplanting losses due to the disease.

1. Barnard, E.L., R.S. Webb, S.P. Gilly, and W.D. Lante. 1985. *Phytophthora cinnamomi* infection in sand pine seedlings in Florida nurseries and effects on outplant survival. IN: International symposium on nursery management practices for southern pines, proceedings, p.486-495. Auburn University and International Union of Forestry Research Organizations, S3.202-03, edited by D.B. South. Held August 4-9, 1985.

Soil samples from seedbeds of *Pinus clausa* in seven bareroot nurseries were analyzed for the presence of *Phytophthora cinnamomi*. The pathogen was detected in only one nursery. 2-0 seedlings from *P. cinnamomi*-infested seedbeds, and which displayed no above-ground symptoms of root disease, exhibited twice the mortality rate of companion seedlings from seedbeds in which the pathogen was not detected during the first 4 months following outplanting on a *P. cinnamomi*-free soil in central Florida. Surviving seedlings from *P. cinnamomi*-infested seedbeds were significantly smaller, after 16 months in the field, than surviving seedlings from seedbeds in which *P. cinnamomi* was not detected.

2. Benson, D.M., L.F. Grand, and E.G. Suggs. 1976. Root rot of Fraser fir caused by *Phytophthora drechsleri*. Plant Disease Reporter 60(3):238-240.

Root rot of *Abies fraseri* caused by *Phytophthora drechsleri* has been demonstrated on field-grown trees and in greenhouse inoculations. Infected plants developed symptoms similar to plants infected with *P. cinnamomi* including chlorosis and

wilting of foliage, root necrosis and sloughing of cortical tissue, and a characteristic red-brown discoloration of the cambial zone extending 3 to 7 cm above soil line. Plants developed symptoms about 30 days after inoculation, whereas incidence of infection was increased under saturated soil conditions.

3. Bruck, R.I. and C.M. Kenerley. 1981. Effect of metalaxyl on Phytophthora root rot of Fraser fir. Phytopathology 71(8):864.

   Experiments were initiated to determine the efficacy of metalaxyl against *Phytophthora cinnamomi*. During 11 sampling periods, *P. cinnamomi* was not isolated from many of the metalaxyl treated plots but was isolated from 27 percent of the untreated plants.

4. Bruck, R.I. and C.M. Kenerley. 1983. Effects of metalaxyl on Phytophthora cinnamomi root rot of *Abies fraseri*. Plant Disease 67:688-690.

   Greenhouse and field experiments were initiated in 1980 to determine the efficacy of metalaxyl (Subdue 2E® and Subdue 15G®) as a control for Phytophthora root root. Two-year-old greenhouse-grown fir trees were protected from *P. cinnamomi* when treated with metalaxyl either before, during, or up to 7 days after soil infestation with fungal propagules. Three-year-old greenhouse-grown seedlings treated with the highest metalaxyl rate (250 ug a.i./ml) as late as 15 days after soil infestation remained asymptomatic and attempts to recover *P. cinnamomi* from their roots were unsuccessful. Survival of *P. cinnamomi* propagules living free in the soil was completely retarded only at a high fungicide rate (250 ug a.i./ml) 7 days posttreatment; however, after 48 days, no propagules were detected at rates>1.0 ug a.i./ml. In nursery bed trials, Fraser fir seedlings were protected from root rot and spread of the fungus within nursery beds was arrested. Metalaxyl may be effectively employed as a prophylactic root rot fungicide against Phytophthora root rot of Fraser fir.

5. Cooley, S.J. 1987. Management of Phytophthora root rot in conifer nurseries of the Pacific Northwest. Tree Planters' Notes 38(4):37-40.

Discusses cultural management of *Phytophthora* by water management, sanitation, resistance, and chemical management by fumigants, fungicides, and chlorination of water.

6. Cooley, S.J. 1987. Management of Phytophthora root rot in Pacific Northwest conifer nurseries. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.125-127. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

Various cultural and chemical strategies to reduce the incidence and severity of Phytophthora root rot on conifers in bareroot nurseries are discussed.

7. Cooley, S.J. and P.B. Hamm. 1988. Susceptibility of Pacific North west conifers to Phytophthora root rot. Tree Planters' Notes (in press).

Seedlings of 11 conifer species were inoculated with 5 species of *Phytophthora* to determine susceptibility to Phytophthora root rot. Pine, cedar, larch and spruce species showed tolerance to the disease, whereas some true fir and hemlock species were quite susceptible. Other species showed intermediate susceptibility. Management of Phytophthora root rot is discussed, utilizing knowledge of relative susceptibility of various conifers grown in the Pacific Northwest.

8. Cooley, S.J., P.B. Hamm, and E.M. Hansen. 1985. Management guide to Phytophthora root rot in bareroot conifer nuseries of the Pacific Northwest. USDA Forest Service, Pacific Northwest Region.

Guidelines are outlined for managing Phytophthora root rot on field-grown seedlings in Pacific Northwest bareroot forest nurseries.

9. Erwin, D.C., S. Bartnicki-Garcia, and P.H. Tsao. 1983. *Phytophthora*: its biology, taxonomy, ecology, and pathology. American Phytopathological Society.

   Comprehensive review of all areas of knowledge related to *Phytophthora*.

10. Goheen, D.J. 1977. Disease evaluation: Westfir Transplant Nursery: 1976. USDA Forest Service, Pacific Northwest Region, Forest Insect and Disease Management.

    Evidence suggested that *Phytophthora* spp. might be causing the considerable mortality and chlorosis that had been occurring in the nursery. Three experiments were conducted: (1) an investigation of in-nursery mortality, to determine the amount and causes; (2) an evaluation of outplanting success of chlorotic trees, to determine culling standards; (3) a fungicide treatment test against root rots. *Phytophthora* spp. appears to be limited to areas of the very poorest drainage. Nutrient imbalances are important in weakening and killing seedlings, especially in the more poorly drained areas. Nutrient deficiencies may predispose seedlings to attack by root disease fungi and are probably responsible for most of the chlorotic foliage observed in the nursery. Outplanting trials suggest that culling standards could be relaxed, as chlorotic trees with full crowns and root systems seem to survive nearly as well as normal trees. Fungicides tests with Banrot® and Truban® soil drench and root dip did not significantly increase survival or vigor of seedlings.

11. Grand, L.F. and N.A. Lapp. 1974. Phytophthora cinnamomi root rot of Fraser fir in North Carolina. Plant Disease Reporter 58(4):318-320.

    Root rot caused by *Phytophthora cinnamomi* has become an increasingly important disease of Fraser fir (*Abies fraseri*) nursery and plantation-grown Christmas trees in North Carolina. An intensive survey was conducted in 1972 to determine distribution and losses due to this disease. Losses in 14 plantations ranged from less than 1 percent to 90 percent with an average of 9.6 percent.

12. Hamm, P.B., S.J. Cooley, and E.M. Hansen. 1984. Response of *Phytophthora* spp. to metalaxyl in forest nurseries in the Pacific Northwest. Plant Disease 68(8):671-673.

In tests on Douglas-fir at two commercial forest tree nurseries in Oregon, one application of Subdue® (metalaxyl) suppressed root rot. Of three *Phytophthora* species isolated from treated seedlings (*P. megasperma, P. drechsleri,* and *P. pseudotsugae),* only *P. pseudotsugae* decreased in isolation frequency because of the fungicide. Survival of *Phytophthora* species in infected seedlings remained high after treatment. At one nursery, 10 months after the first application, *Phytophthora* species were isolated from 92 percent of the seedlings across fungicide treatments, whereas at the second nursery, isolation frequencies from seedlings were 77, 70, 29 and 13 percent respectively, after 0, 1, 2, and 3 applications. *Phytophthora* was recovered from previously healthy seedlings 8 weeks after they were transplanted into naturally infested, metalaxyl-treated soils.

13. Hamm, P.B. and E.M. Hansen. 1981. Host specificity of *Phytophthora megasperma* from Douglas fir, soybean, and alfalfa. Phytopathology 71:65-68.

A total of 28 isolates of *Phytophthora megasperma* from either Douglas-fir, alfalfa, or soybean were tested for pathogenicity to Douglas-fir, alfalfa and soybean. Isolates from alfalfa and soybean were pathogenic only to their original hosts. One group of isolates from Douglas-fir was strongly pathogenic to both Douglas-fir and soybean; a second group was less pathogenic to Douglas-fir and was not pathogenic to soybean. The first group from Douglas-fir was virulent on seven soybean cultivars used to define races of *P. megasperma* f. sp. *glycinea* and on cultivar Tracy. Applicability of the formae speciales concept to *P. megasperma* is discussed.

14. Hamm, P.B. and E.M. Hansen. 1982. Pathogenicity of *Phytophthora* species to Pacific Northwest conifers. European Journal of Forest Pathology 12(3):167-174.

Phytophthora cactorum was recovered from nursery seedlings of *Pseudotsuga menziesii, Abies amabalis,* and *A. procera,* and *Phyto-*

phthora megasperma from *Pinus lambertiana* in a seed orchard in Oregon. Isolates of *P. cryptogea* from pine and *Abies* species in two locations differed in pathogenicity and colony appearance. On inoculation of seedlings of 9 northwest conifers, *P. megasperma* group 1 isolates, *P. cryptogea* and *P. cinnamomi* were pathogenic to all except *Thuja plicata*. *Tsuga heterophylla* and *Abies* species were susceptible to most species tested. *Pinus ponderosa* and *P. lambertiana* were damaged only by *Phytophthora cryptogea* and *P. cinnamomi*. *Thuja plicata* was resistant to all isolates.

15. Hamm, P.B. and E.M. Hansen. 1983. *Phytophthora pseudotsugae*, a new species causing root rot of Douglas-fir. Canadian Journal of Botany 61(10):2626-2631.

    The new species was isolated from rotted roots of *Pseudotsuga menziesii* in forest tree nurseries in Oregon and Washington. It is distinguished by large oogonia and oospores, mostly paragynous antheridia, and predominately spherical or ovoid, persistent sporangia borne primarily on simple and unbranched sporangiophores. Sporangia are formed occasionally in liquid culture, rarely on solid media. *P. pseudotsugae* is distinguished most readily from *P. cactorum* by its unbranched sporangiophores and persistent sporangia, in growth on defined media, electrophoretic protein patterns and pathogenicity. It is also compared with *P. iranica*.

16. Hamm, P.B., E.M. Hansen, and J.R. Sutherland. 1985. *Phytophthora cryptogea* and *P. drechsleri* associated with root-rotted Douglas-fir seedlings in British Columbia. Plant Disease 69(4):361.

    The fungi were isolated from diseased roots of 2-year-old bare-root *Pseudotsuga menziesii* seedlings with stunting, chlorosis, and poor root development, the first report of a Phytophthora root rot in a British Columbia forest nursery (which extends the northern range of this disease on *Pseudotsuga menziesii*).

17. Hansen, E.M., P.B. Hamm, A.J. Julis, and L.F. Roth. 1979. Isolation, incidence and management of *Phytophthora* in forest tree nurseries in the Pacific Northwest. Plant Disease Reporter 63(7):607-611.

Root rot, caused by *Phytophthora* species, of Douglas-fir and cedar, was most frequent in poorly drained beds on root-pruned transplanted trees.

18. Hansen, E.M., L.F. Roth, P.B. Hamm, and A.J. Julis. 1980. Survival, spread, and pathogenicity of *Phytophthora* spp. on Douglas-fir seedlings planted on forest sites. Phytopathology 70(5):422-425.

Seedlings of *Pseudotsuga menziesii* infected in the nursery with *Phytophthora cryptogea, P. dreschsleri, P. megasperma, P. cactorum* and an unidentified *P.* species were outplanted on commercial forest sites. Mortality of trees, initially classified with severe, moderate and inconspicuous symptoms, subsequently reached 61, 26 and 11 percent respectively, after 18 months. *Phytophthora* was recovered about equally from roots of trees in each symptom class (15, 13 and 12 percent). Surviving trees regenerated healthy roots above old lesions even though *Phytophthora* persisted. Disease spread was limited. None of 360 healthy trees planted 0.6 m downslope from diseased trees became infected, and only 2 of 270 healthy trees became infected after each was paired with a diseased tree in the same planting hole.

19. Hunger, R.M., P.M. Hamm, C.E. Horner, and E.M. Hansen. 1982. Tolerance of *Phytophthora megasperma* isolates to metalaxyl. Plant Disease 66:645-649.

Thirty-five isolates of *Phytophthora megasperma* were tested in vitro for tolerance to the systemic fungicide metalaxyl. Isolates had been collected before commercial use of metalaxyl. Tolerance was measured by comparing isolate growth and oogonia and sporangia formation on amended and control media. Based on growth at 0, 1, and 10 micrograms/ml metalaxyl, 15 isolates were highly sensitive, eight were moderately tolerant, and 12 were highly tolerant of the fungicide. No isolates in the highly sensitive group formed oogonia at 1 microgram/ml,

whereas six isolates from the moderately tolerant group and eight from the highly tolerant group did. The number of isolates that formed sporangia and the mean number of sporangia formed per isolate decreased with increasing fungicide concentration. At least two of 280 single-zoospore isolates were more tolerant to metalaxyl than their parents, suggesting that commercial applications of the fungicide may select for naturally occurring tolerant strains, which may in turn lead to loss of disease control.

20. Kenerley, C.M. and R.I. Bruck. 1983. Overwintering and survival of *Phytophthora cinnamomi* in Fraser fir and cover cropped nursery beds in North Carolina. Phytopathology 73:1643-1647.

Phytophthora cinnamomi survived extended periods of soil temperatures at or below 0 degrees C for two consecutive winters as chlamydospores free in the soil, in pieces of organic matter, or in roots of symptomatic and asymptomatic Fraser fir (*Abies fraseri*) seedlings. Inoculum densities decreased markedly in December and January as soil temperatures fell below 0 degrees C. Decreasing inoculum densities were found to be highly correlated with decreasing soil temperatures. Soil matric potential, soil texture, initial inoculum density, or seedling age were not correlated with decreasing inoculum densities. Propagules of *P. cinnamomi* were recovered at every sampling date (October to June) from nonrhizosphere soil in plots with Fraser fir, crimson clover, rye, or left fallow and from rhizosphere soil of crimson clover and rye plants. Chlamydospores were the most frequent form of *P. cinnamomi* isolated from the soil or root tissue during the winter and spring months. Survival of *P. cinnamomi* in the roots of asymptomatic seedlings demonstrated that foliar symptom expression is not a reliable indicator of the incidence of infection within a nursery bed.

21. Kenerley, C.M. and R.I. Bruck. 1987. Distribution and disease progress of Phytophthora root rot of Fraser fir seedlings. Phytopathology 77:520-526.

The movement of *Phytophthora cinnamomi* from infested into noninfested portions of five disease focus plots was monitored

by quantifying inoculum density of soil samples and recording Fraser fir seedling mortality. Comparison of overlapping inoculum density contour maps with regard to changes in inoculum density, new area infested, and shift in area of highest inoculum density revealed four patterns of propagule distribution. Inoculum density maxima were recorded August 26 and September 8. Greatest increases in total mortality of seedlings also occurred during this period of the growing season. Final cumulative mortality was not correlated with initial inoculum density or seedling density. Seedling mortality was recorded in areas of each plot previously noninfested, but area of propagule detection was more extensive than that of seedling mortality. Plots of calculated relative rates of disease increase vs. the cumulative seedling mortality illustrated fluctuations in disease progression, indicating a lack of fit with widely acceptable models.

22. Kenerley, C.M., K. Papke, and R.I. Bruck. 1984. Effect of flooding on development of Phytophthora root rot in Fraser fir seedlings. Phytopathology 74:401-404.

Soil infested with propagules of *Phytophthora cinnamomi* but without seedlings, and infested and uninfested soil into which 2-year-old *Abies fraseri* seedlings were transplanted, was continuously flooded for 0, 24, and 48 hours. Inoculum density of *P. cinnamomi* was quantified at 2, 9, and 23 days and seedling mortality was assessed 33 days after flooding. In treatments with infested soil and seedlings, inoculum density was greater with flooding than without flooding at days 9 and 23. Final seedling mortality and infection were also higher with the two flooding treatments compared to no flooding. Inoculum density was found to decline similarly among the treatments without the host regardless of the flooding period. A separate series of experiments demonstrated that significant increases in the production of secondary inoculum occurred within 3 days of flooding infested soil containing the host. The greatest rate of increase in secondary inoculum was recorded between days 5 and 7 following flooding. In experiments with zoospore suspensions used as inoculum, no difference in seedling infection was found between flooded or unflooded treatments at any inoculum levels tested. Flooding appears to increase seedlings infection and mortality by promoting production and dispersal of inoculum rather than predisposing the host.

23. Kuhlman, E.G. 1964. Survival and pathogenicity of *Phytophthora cinnamomi* in several western Oregon soils. Forest Science 10(2):151-158.

Survival of *Phytophthora cinnamomi* in forest soils in bottles, as measured by successful reisolation, dropped steadily during the first six months following inoculation, and remained nearly constant at a very low level up to 19 months, after which it could not be isolated. The presence of small *Pseudotsuga menziesii* seedlings did not prolong survival time. Chlamydorores are regarded as the principal survival structures. Mycelial growth was inhibited throughout the year in both forest and cultivated soil. The fungus, a poor competitive soil saprophyte, failed to colonize Douglas-fir twigs when the surrounding soil mixture contained less than 50 percent alfalfa meal-sand inoculum. Contrarily, in sterilized forest soils growth was rapid at moisture levels of 43 and 58 percent and at temperature between 15 and 25 degrees C. Zoospores germinated with subsequent sporangial formation on fir root tips at 15 and 30 degrees C. In unsterilized soil filtrate, zoospores swam to Douglas-fir roots 3 inches away, but in wet soil, less than 1 inch was transversed. Prolonged low soil moisture was fatal to the fungus.

24. Kuhlman, E.G. and F.F. Hendrix, Jr. 1963. Phytophthora root rot of Fraser fir. Plant Disease Reporter 47(6):552-553.

Abies fraseri is a new host for *Phytophthora cinnamomi* and showed a high degree of susceptibility in a nursery where conditions were conducive to disease development. *P. cinnamomi* was readily isolated from diseased seedlings. Dexon® applied twice at rates of 80 and 120 lb/acre reduced losses but did not provide a practical control in nursery beds.

25. MacDonald, J.D. 1982. Role of environmental stress in the development of Phytophthora root rots. Journal of Arboriculture 8(8):217-223.

The experimental evidence reviewed shows that stresses to plant roots caused by oxygen deficiency, water stress, or salinity, can predispose roots to infection and disease caused by

Phytophthora species. These findings are significant because they show that environmental factors actually exert a determining role in tissue susceptibility.

26. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Phytophthora root rot.

27. Pratt, R.G., L.F. Roth, E.M. Hansen and W.D. Ostrofsky. 1976. Identity and pathogenicity of species of *Phytophthora* causing root rot of Douglas-fir in the Pacific Northwest. Phytopathology 66(6):710-714.

Three *Phytophthora* species previously unreported on *Pseudotsuga menziesii* were isolated, with *P. cinnamomi*, from diseased trees in forest nurseries, forest outplantings and seedling storage facilities in western Oregon and Washington. Two were identified as *P. cryptogea* and *P. drechsleri*. The third did not correspond to any previously described species. *P. cinnamomi* and *P. cryptogea* were highly virulent on dormant and growing seedlings in greenhouse tests. *P. drechsleri* and the third *Phytophthora* species were less virulent. All three are similar to *P. lateralis*, a destructive pathogen of *Chamaecyparis lawsoniana* in growth at low temperatures, and should therefore be regarded as potentially dangerous forest pathogens in cool, moist sites.

28. Reynolds, K.M., D.M. Benson and R.I. Bruck. 1985. Epidemiology of Phytophthora root rot of Fraser fir: root colonization and inoculum production. Phytopathology 75:1004-1009.

The purpose of the research reported here was to examine certain aspects of host-pathogen interaction that are required for the development of a biologically-based epidemiological model. In particular, the model was based on environmental factor effects on rate of root colonization, chlamydospore production, and sporangia production in nursery beds of *Abies fraseri* seedlings affected by *P. cinnamomi*.

29. Roth, L.F. and E.G. Kuhlman. 1966. *Phytophthora cinnamomi*, an unlikely threat to Douglas-fir forestry. Forest Science 12(2):147-159.

Phytophthora cinnamomi has damaged forests around the world in regions with mild climates. Its pathogenesis on Douglas-fir in southern Europe and the southeastern United States suggested a potential threat to Douglas-fir forests of the Pacific Coast. Concern increased in 1950 with discovery of *P. cinnamomi* in nurseries growing ornamentals and in landscape plantings in western Oregon and Washington, and research was undertaken to evaluate the threat. A temperature of 60 degrees F was found necessary for infection. While summer soil temperatures on south exposures are above 60 degrees F most of the time from June to October, soil moisture is continuously below field capacity and too dry for infection. On north exposures, summer soil moisture is adequate but temperatures are too low; 60 degrees F is reached for only a few hours near the first of August. Forest soils of western Oregon are generally too dry for infection during the summer. The fall rains provide necessary moisture but concurrently depress temperature below the critical 60 degrees F. Adverse soil temperature and moisture influence disease by impeding infection rather than reducing survival of *P. cinnamomi*. The disease in ornamentals is sustained by summer irrigation of warm locations such as the south side of buildings. The data show that *P. cinnamomi* is unlikely to become a problem in forests of the Pacific Northwest.

30. Schmitthenner, A.F. 1970. Significance of populations of *Pythium* and *Phytophthora* in soil. IN: Root disease and soil-borne pathogens, p.25-27, edited by T.A. Toussoun, R.V. Bega, P.E. Nelson. University of California Press.

High soil moisture is necessary for development for root and seed rots caused by *Pythium* and *Phytophthora*. The primary effect of high soil moisture is decreased oxygen. Both *Pythium* and *Phytophthora* grow well in low oxygen that may damage higher plants. *Pythium* and *Phytophthora* might be controlled more easily by manipulating soil moisture, where this is possible, than by attempting to eliminate the pathogens.

31. Shew, H.D. 1981. Fraser fir root rot induced by *Phytophthora citricola.* Plant Disease 65(8):688-689.

Root rot of Fraser fir (*Abies fraseri*) caused by *Phytophthora cinnamomi* and *P. drechsleri* is a limiting factor in the production of Fraser fir as a Christmas tree species in western North Carolina. Severe losses occur in nurseries and in plantations. In routing isolations from Fraser fir seedlings exhibiting typical root rot symptoms, a different *Phytophthora* species was isolated. The fungus was identified as *P. citricola,* based on characteristic morphological features.

32. Shew, H. 1983. Influence of soil temperature and inoculum density of *Phytophthora cinnamomi* on root rot of Fraser fir. Plant Disease 67(5):522-524.

Fraser fir (*Abies fraseri*) is the most important species in the Christmas tree industry in North Carolina, and production of the species in nurseries and plantations is limited in some locations by root rot caused by *Phytophthora cinnamomi.* Knowledge of the effect of initial inoculum density of *P. cinnamomi* in soil on infection and mortality of Fraser fir is required to understand the epidemiology of Phytophthora root rot under nursery conditions and to identify low-hazard planting sites for Fraser fir plantations. Although significant root infection took place at 12 and 14 degrees C., foliar symptoms were not expressed by infected seedlings when incubated below 16 degrees C. The minimum level of *P. cinnamomi* inoculum in soil required for infection and mortality of Fraser fir seedlings was determined to be fewer than 10 chlamydospores per kilogram of soil.

33. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p. 203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating

birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

34. Zentmyer, G.A. 1980. *Phytophthora cinnamomi* and the diseases it causes. American Phytopathological Society, Monograph 10.

This comprehensive monograph covers all aspects of *Phytophthora cinnamomi*, including its range of hosts, geographical origin, characteristic morphological features, pathogenesis, and genetics. Also described are the effect of environment on the fungus, and control of the diseases it causes. A variety of control methods are discussed - prevention, chemical control, biological control, and resistance.

Sirococcus Tip Blight

(Sirococcus strobilinus)

We include 26 references on Sirococcus tip blight. Most of them report work carried out in Idaho, northern California and British Columbia, Canada, on spruce, western hemlock, and various pine species. Four papers discuss aspects of the biology of *Sirococcus* (3, 18, 23, 25); 3 report results of chemical trials (2, 9, 19); and one deals with the relative susceptibility of various lodgepole pine provenances to the disease (4). A large number of papers are detection or impact reports (1, 5, 6, 7, 8, 13, 16, 17, 26); there are also three references which cover methods to detect the fungus in seed (10, 11, 22). Six general references on biology and control are listed as well (12, 14, 15, 20, 21, 24).

1. Anonymous. 1980. Two new seed diseases discovered. Canadian Forestry Service, Pacific Forest Research Centre, Information Forestry 7(4):7.

Researchers at the Pacific Forest Research Centre have recently discovered two new seed-borne diseases which held account

for some of the previously unexplained sowing losses in local nurseries. The first, *Caloscypha fulgens*, is found on about one-third of all spruce seedlots tested and on about one-fourth of *Abies* seedlots tested. It was determined that the seeds become diseased when they come in contact with forest duff. The second disease, caused by the fungus *Sirococcus strobilinus*, is perhaps more significant because it affects seeds and also conifer regeneration and nursery seedlings, especially in young spruce seedlings in container nurseries.

2. Freeman, W.L., Jr. 1984. Efficacy of three fungicides for control of Sirococcus tip blight of Jeffrey pine at the Humboldt Nursery. USDA Forest Service, Pacific Southwest Region, Report 84-38.

Fungicide trials in 1983 indicated that three fungicides — chlorothalonil, triadimefon, and ectaconazole — effectively controlled Sirococcus tip blight of Jeffrey pine.

3. Funk, A. 1972. Sirococcus shoot-blight of western hemlock in British Columbia and Alaska. Plant Disease Reporter 56(8):645-647.

Sirococcus strobilinus is the cause of shoot-blight disease of western hemlock in coastal British Columbia and in the Alaska panhandle. The disease was artificially induced in potted trees by spraying with a conidial suspension after a dark treatment. The severity of Sirococcus shoot-blight appears to be linked with light intensity in the stand. Its common occurrence in suppressed or crowded trees indicates greater susceptibility in this species, which survives in a suppressed state.

4. Illingworth, K. 1973. Variation in the susceptibility of lodgepole pine provenances to Sirococcus shoot blight. Canadian Journal of Forest Research 3(4):585-589.

Sirococcus strobilinus was identified as the cause of a shoot blight of *Pinus contorta* seedlings grown in a nursery provenance trial in British Columbia. Marked variation in susceptibility to this fungus was noted among the 153 provenances present, which were representative of the entire range of *P. contorta* in western North America. Genetic variation in host susceptibility is inferred.

5. James, R.L. 1983. Fungi associated with tip dieback of ponderosa pine seedlings at the Clifty View Nursery, Bonners Ferry, Idaho. USDA Forest Service, Northern Region.

   1-0 ponderosa pine seedlings were examined to determine possible causes of tip dieback and necrosis. *Sirococcus strobilinus* was isolated from 10 percent of the seedlings received. *Phoma eupyrena* and *P. herbarum* were commonly found sporulating on and were isolated from necrotic tissues both at the tips and at the base of affected seedlings. *Diplodia pinea* was infrequently isolated from tip blighted seedlings. *Epicoccum nigrum* was commonly isolated from necrotic stem and needle tissues. In addition, four isolates of *Sirococcus strobilinus* were screened for possible tolerance to chlorothalonil. The isolates examined were not very tolerant; however, sustained heavy doses of the fungicide may select for more tolerant strains of the fungus.

6. James, R.L. 1983. *Sirococcus strobilinus* on containerized Engelmann spruce seedlings at the Coeur d'Alene Nursery, Idaho. USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management, Report 83-20.

   During the spring of 1983, dead and dying containerized *Picea engelmannii* seedlings, about 1 month old, were examined at the Coeur d'Alene Nursery. Growers thought the mortality was caused by damping-off fungi, but close examination showed that affected seedlings remained upright instead of falling over, as expected with damping-off. Microscopic examination revealed the presence of the black fruiting bodies of *S. strobilinus*.

7. James, R.L. 1985. Sirococcus tip blight on bareroot Engelmann spruce seedlings at the Clifty View Nursery, Bonners Ferry, Idaho. USDA Forest Service, Northern Region.

   Sirococcus strobilinus was confirmed on bareroot Engelmann spruce seedlings at the Clifty View Nursery for the first time during the fall of 1984. The disease caused tip and lateral branch dieback and some mortality to scattered seedlings throughout several seedbeds. Chlorothalonil treatments plus

hand sanitation did not completely control the disease. Diseased seedlings should be removed from the nursery rather than discarded on the ground near seedbeds. Other fungicides which may be useful in controlling this disease are listed.

8. James, R.L. 1985. Top blight of bareroot ponderosa and lodgepole pine seedlings at the USDA Forest Service Nursery, Coeur d'Alene, Idaho. USDA Forest Service, Northern Region.

   Top blight caused by *Sirococcus strobilinus* was confirmed on bareroot ponderosa and lodgepole pine seedlings for the first time at the Coeur d'Alene Nursery. *Fusarium oxysporum* was also frequently isolated from blighted seedlings. Top blight was most prominent during the spring of 1984; by mid-summer, little disease was noticeable. Although the disease was not severe enough to warrant direct control measures, alternatives to reduce losses in the future are discussed.

9. Kliejunas, J. 1983. Fungicide trials for control of *Phoma* and *Sirococcus* at the Humboldt Nursery. IN: Western International Forest Disease Work Conference, 31:50-53.

   Ten fungicides to control Phoma blight of red fir and five fungicides to control Sirococcus tip blight of Jeffrey pine were evaluated at the Humboldt Nursery. Fungicides were applied at approximately one month intervals from September 1982 to May or June 1983. Efficacy was determined by comparing the percentage of red fir killed or Jeffrey pine cankered in each treated plot with adjacent untreated plots. None of the fungicides tested effectively controlled Phoma blight of red fir. Three fungicides — chlorothalonil, ectaconazole, and triadimefon — were efficacious in controlling Sirococcus tip blight of Jeffrey pine; vinclozolin and iprodione were not.

10. Mitchell, L.A. 1986. Derivation of *Sirococcus strobilinus* specific monoclonal antibodies. Canadian Journal of Forest Research 16:939-944.

    Cloned hydridoma cell lines producing monoclonal antibodies to *Sirococcus strobilinus* have been prepared by immunizing

BALB/c mice with whole mycelium and fusing their spleen cells with SP2/0-Ag14 myeloma cells. Specificity for *S. strobilinus* was ascertained by testing the monoclonal antibodies in enzyme-linked immunosorbent assays and by indirect surface immunofluorescence tests against a panel of seven nonrelated commensal fungi obtained from the same seed lot as the *Sirococcus* isolate used in the derivation of the monoclonal antibodies. The monoclonal antibodies produced by these selected hybridoma cell lines also recognize antigens from other *S. strobilinus* isolates from diverse host species and tissues. The monoclonal reagents will thus be useful as diagnostic probes for locating *S. strobilinus* in or on seed and other plant tissues. Preliminary characterization of the morphologic distribution of antigens recognized by the monoclonal antibodies is discussed.

11. Mitchell, L.A. and J.R. Sutherland. 1986. Detection of seed-borne *Sirococcus strobilinus* with monoclonal antibodies in an enzyme-linked immunosorbent assay. Canadian Journal of Forest Research 16:945-948.

    A quantitative indirect enzyme-linked immunosorbent assay (ELISA) employing *Sirococcus strobilin*us specific monoclonal antibodies has been developed for use in screening spruce seed extracts for this seed-borne fungal pathogen. The ELISA, which is one of the first applications of monoclonal antibodies in immunodetection of conifer fungi, offers several advantages over the currently used "detection by plating" technique for seed-borne pathogens. It is sensitive, detecting less than 25 ng of fungal protein, specific, and is not subject to interference from saprobes. The ELISA is also rapid, giving results within 24 hours, and is relatively easy to perform, allowing simultaneous screening of up to 96 seed lots in a single microassay plate.

12. Nicholls, T.H. and K. Robbins. 1984. Sirococcus shoot blight. USDA Forest Service, Forest Insect and Disease Leaflet 166.

    Reviews hosts, damage, symptoms, life cycle and cultural control methods.

13. O'Brien, J.T. 1973. Sirococcus shoot blight of red pine. Plant Disease Reporter 57(3):246-247.

Sirococcus strobilinus has been identified as the cause of a shoot blight of *Pinus resinosa* in the Lake States.

14. Peterson, G.W. and R.S. Smith: 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including Sirococcus tip blight.

15. Riffle, J.W. and G.W. Peterson. 1986. Diseases of trees in the Great Plains. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-129.

Discusses hosts, distribution, symptoms and signs, disease cycle, damage and control of a variety of diseases, including Dothistroma blight of pines, Sirococcus shoot blight and western gall rust.

16. Schwandt, J.W. 1981. Sirococcus tip blight in north Idaho nurseries. Idaho Department of Lands, Report 81-7.

Sirococcus tip blight was discovered late in the summer of 1980 in two Bonners Ferry, Idaho, nurseries causing severe damage to 1-year-old ponderosa pine seedlings. Symptoms follow a distinct pattern resulting in a tip dieback of new shoots and substantial mortality in 1-0 seedlings. A spray program using chlorothalonil coupled with the onset of cold weather reduced spread in the fall of 1980. A resurgence of the disease the following spring was observed and additional sprays were only partially successful in preventing further losses. Poor results may be attributed to an unusually long, moist spring and frequent overhead watering during summer months. Change in irrigation and spray schedules are planned for the 1982 growing season.

17. Shahin, E.A. and L.E. Claflin. 1978. The occurrence and distribution of Sirococcus shoot blight of spruce in Kansas. Plant Disease Reporter 62(7):648-650.

    Sirococcus strobilinus was identified as the causal agent of shoot-blight disease of spruce in Kansas. This is the first known occurrence of the pathogen in the Central United States, and it may pose serious problems to spruce and other conifer plantings. Observations in one of the nurseries in which Sirococcus shoot blight was the only disease present indicates that this disease is potentially disastrous. Sirococcus shoot blight was detected in nine geographically separate counties in Kansas. Such geographical separation suggests that the pathogen was introduced into the various locations on infected nursery stocks. The resemblance of symptoms to winter injury and other physiological disorders may explain the failure to detect the disease in previous years.

18. Smith, R.S., Jr. 1973. Sirococcus tip dieback of *Pinus* spp. in California forest nurseries. Plant Disease Reporter 57(1):69-73.

    Reports *S. strobilinus* on 1- and 2-year-old seedlings of *Pinus coulteri, P. jeffreyi, P. lambertiana,* and *P. ponderosa* in two coastal nurseries in northern California. Spore cultures germinated and grew best at 15 to 20 degrees C, and poorly at <10 degrees. Artificial inoculation transmitted the disease to 3-month-old seedlings; field observations suggest that only the current year's growth is attacked. It is concluded that the disease is a problem only in late spring and summer under mild humid conditions, and is unlikely to spread inland.

19. Smith, R.S., Jr., A.H. McCain, M. Srago, R.F. Krohn, and D. Perry. 1972. Control of Sirococcus tip blight of Jeffrey pine seedlings. Plant Disease Reporter 56(3):241-242.

    In test plots chlorothalonil and a combination product of zinc ion and maneb sprayed once every two weeks successfully controlled the tip blight of 2-0 Jeffrey pine seedlings caused by *Sirococcus strobilinus*.

20. Srago, M.D. 1978. Nursery disease problems - *Sirococcus strobilinus*. IN: Western Forest Nursery Council and Intermountain Nurseryman's Association, Combined Conference and Workshop Proceedings, 1978, p. B134-B137.

Sirococcus strobilinus is a major problem in the Jeffrey pine and ponderosa pine at the Humboldt Nursery on the California coast. This study suggests that the disease will continue to be a problem only in late spring and summer along the coast, where mild temperatures prevail and moisture is available. This information suggests a possible timing of effective fungicide applications to control this disease.

21. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p. 203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

22. Sutherland, J.R., W. Lock, and S.H. Farris. 1981. Sirococcus blight: a seed-borne disease of container-grown spruce seedlings in coastal British Columbia forest nurseries. Canadian Journal of Botany 59(5):559-562.

This blight, caused by *S. strobilinus,* affects *Picea sitchensis, P. glauca, P. engelmannii* and *P. glauca x P. engelmannii.* The fungus was best detected by germinating seed, from seedlots with consistent disease histories, in autoclaved soil in pots (at 16 to

20 degrees C with light intensities of 900 to 1,800 lux), and isolating from diseased seedlings. Seed-borne isolates were pathogenic to *P. sitchensis* seedlings. The pathogen was present on 0.3 to 3.1 percent of the seed of infested seedlots. Seeds with shrunken contents yielded it 7 to 9 times more often than those whose contents appeared normal. Disease incidence was unrelated to seedcoat damage or prevalence of empty seeds. The pathogen was found throughout the endosperm and embryo tissues.

23. Sutherland, J.R., W. Lock, T.A.D. Woods, and T. Suttill. 1982. Sirococcus blight not seed-borne on serotinous lodgepole pine. Canadian Forestry Service, Research Notes 2(3):20-21.

    Recently, it has been determined that *S. strobilinus* is seed-borne on spruces. With improved techniques for detecting seed-borne *S. strobilinus*, Illingworth's findings (Can. J. For Res. 3:585-589) that the fungus was not seed-borne on *Pinus contorta* were re-examined. Three experiments were done and *S. strobilinus* was not obtained from any of the 24 lodgepole pine seedlots. Results confirm Illingworth's findings that the fungus is not seed-borne on lodgepole pine and also substantiate his report that lodgepole pine provenances vary in susceptibility to Sirococcus blight.

24. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

    Reviews hosts, damage, life history and control of various nursery diseases, including damping-off, Fusarium root rot, Sirococcus blight, gray mold, western gall rust, and storage molds.

25. Wall, R.E. and L.P. Magasi. 1976. Environmental factors affecting Sirococcus shoot blight of black spruce. Canadian Journal of Forest Research 6(4):448-452.

    Isolates of *S. strobilinus* were obtained from nurseries in New Brunswick and Prince Edward Island for laboratory studies.

The most rapid growth of cultures and germination of pycnidia occurred at 25 degrees C. Exposure to 35 degree C was lethal to mycelium after 7 days and to pycnidia after 2 days. The fungus survived exposure to -10 degrees C and to outdoor conditions for several weeks. Light did not affect conidial germination or mycelial growth but was essential for pycnidial formation. Infection of inoculated *Picea mariana* seedlings was most rapid and symptoms most pronounced in the temperature range of 16 to 21 degrees C. Infection was greater at low than at high light intensity. The percentage of infected plants increased with increasing number of days at high humidity.

26. Wicker, E.F., T.H. Laurent, and S. Israelson. 1978. Sirococcus shoot blight damage to western hemlock regeneration at Thomas Bay, Alaska. USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Paper INT-198.

    Clearcut areas regenerated to western hemlock and Sitka spruce in southeastern Alaska were surveyed for damage by Sirococcus shoot blight. A disease index was calculated for potential crop trees. All western hemlock regeneration was infected. Disease severity was greater in suppressed and intermediate than in dominant and codominant crown classes. Mortality and severe top-killing were restricted to suppressed and intermediate crown classes. Disease severity was greater in the lower crown than in the upper crown of potential crop trees. Terminal leader kill in potential crop trees was common. Direct measures of disease control are not recommended; however, establishment of nurseries in southeast Alaska for production of western hemlock planting stock would be a high risk adventure. *Sirococcus strobilinus* is capable of causing severe losses in nurseries because the environment usually favors development of the disease.

Storage Molds

We have listed 15 references on storage molds that occur on forest tree seedlings and, of those, 5 are specific to the Pacific Northwest (1, 2, 7, 8, 14). Storage molds are caused by a number of different fungi. There are five references dealing with general management strategies (1, 6, 7, 9, 11); four describe detection and impact on some host plants

(4, 5, 12, 15); and one each describes chemical control (13) and pest biology (14). Control is best achieved through the manipulation of storage practices and environment (2, 3, 8, 10).

1. Carlson, L.W. 1972. Forest tree nursery disease control. IN: Western Forest Nursery Council and Intermountain Forest Nurserymen's Association, Proceedings of Joint Meeting, 1972, p.111-114. Edited by H.W. Anderson, J.A. Bryan, R.P. Eide. Held August 8-10, 1972, Olympia, Washington.

   Reviews chemical and cultural practices for control of the major disease problems: damping-off, gray mold, *Lophodermium*, and storage molds.

2. Duffield, J.W. and R.P. Eide. 1959. Polyethylene bag packaging of conifer planting stock in the Pacific Northwest. Journal of Forestry 57:578-579.

   The use of bags for shipping of forest planting stock is advocated, instead of shipping with tops exposed to air and light. The bags are easier to handle and ship, and the amounts of both peat and water can be reduced in this package as compared with the older band package. Experience also indicates that storage in completely-closed bags results in freedom from molds, provided the temperature is kept between 32 and 35 degrees F.

3. Eliason, E.J. 1962. Damage in overwinter storage checked by reduced moisture. Tree Planters' Notes 55:5-7.

   Serious losses of planting stock due to molding has occurred in artificially refrigerated cold storage facilities. It appears that trees should be put in storage "field dry" and moisture should be carefully added only to the moss surrounding the roots or to the storage facility to maintain the proper humidity.

4. Hinesley, L.E. 1982. Cold storage of Fraser fir seedlings. Forest Science 28(4):772-776.

Seedlings (3-0) lifted in December 1978 were stored at 4 degrees C in kraft-polyethylene bags with 6 root packing methods: bare roots; hydromulch; mud slurry; Canadian peat; sterile Canadian peat; and sphagnum moss. Seedlings lifted in April 1979 were stored with bare roots. All seedlings were planted in May and examined in November 1979. Including root packing materials in the bags produced no improvement over bare-root storage, and mud slurry and hydromulch significantly reduced height growth. In a second experiment, seedlings were lifted in November 1979 or March 1980 and stored at 4 or -3 degrees C. Storage at -3 degrees C inhibited mold, particularly if plants had wet foliage. Overall, survival and growth of plants lifted in November or December were equal to or better than those of plants lifted in spring. Terminal bud abortion was negligible for plants lifted in December and 18 to 31 percent for those lifted in March and April.

5. Hocking, D. 1981. Effect and characteristics of pathogens on foliage and buds of cold-stored white spruce and lodgepole pine seedlings. Canadian Journal of Forest Research 1(4):208-215.

Molding of cold-stored, spring-lifted seedlings of *Picea glauca* reached an index of 71.7 and of *Pinus contorta* an index of 35.6 during 10 weeks of storage. Mortality and reduced growth after planting out were directly related to the degree of molding. Of 37 fungus species isolated from moldy seedlings, 10 were considered significant and were further studied. All 10 grew at 5 degrees C and eight of them grew at 0 degrees C. All 10 were able to infect moist foliage at 2 degrees C, but only *Epicoccum purpurascens* could infect dry foliage, and then only at 95 percent r.h. Storage at 0 degrees C reduced molding to less than one-half that at 25 degrees C. Suitable seedling storage methods are discussed.

6. Hocking, D. and R.D. Nyland. 1971. Cold storage of coniferous seedlings: a review. State University College of Forestry, Syracuse, Applied Forestry Research Institute, AFRI Research Report 6.

   A review and annotated bibliography covering: the need for cold storage; condition of stock entering storage; materials for wrapping around roots; moisture relations; seedling physiology; temperature; storage molds and their control; duration of storage; and responses following storage.

7. Hopkins, J.C. 1975. A review of moulding of forest nursery seedlings in cold storage. Canadian Forestry Service, Pacific Forest Research Centre, Report BC-X-128.

   Literature on molding of forest nursery seedlings in cold storage is reviewed, with separate sections on etiology and damage, factors influencing the occurrence and severity of molding, and control procedures. The system for storage in British Columbia is described and the prospects for mold control are examined for probable applicability there. Research needs are identified.

8. Hopkins, J.C. 1980. Storage moulds. IN: Western Forestry Conference, Proceedings, 1980, p.58.

   Control of molds on bareroot stock has been achieved by such measures as storage at approximately -2 degrees C for interior stock and reduced period in storage for coastal species.

9. Navratil, S. 1973. Pathological and physiological deterioration of planting stock in cold storage (literature review). Ontario Ministry of Natural Resources, Division of Forests, Forest Research Branch, File Report.

   Reviews literature on methods to prevent mold damage and dehydration of planting stock in cold storage.

10. Nyland, R.D. 1974. Sub-freezing temperatures control storage molding. State University of New York, Syracuse, Applied Forestry Research Institute, AFRI Research Note 11.

Observations in New York have shown that storage mold forms when temperatures are kept in the upper 30's or higher. At 32 degrees F, only four species develop to any degree, and then slowly. Below freezing, growth is effectively inhibited. By instituting below-freezing storage, the nursery staff have controlled molding and reduced losses during over-winter cold storage.

11. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including storage molds.

12. Racey, G.D., C. Glerum, and R.E. Hutchison. 1985. Lifting and overwinter storage of white pine in southern Ontario. Forestry Chronicle 61(6):480-483.

In studies at St. Williams nursery, 3-0 *Pinus strobus* was lifted during autumn on seven dates in 1977 and four in 1978. Seedlings were stored cold (1 to 4 degrees C) or frozen (-3 degrees C) and planted out in spring at three sites in 1978 and two sites in 1979. Survival and height were measured after four seasons in the field. Cold storage generally produced better survival and height growth, particularly with stock lifted before accumulation of 125 degree hardening days. Overwinter cold storage is not recommended, however, because of mold development. Stock lifted late in the autumn did not perform as well in the field.

13. Smith, R.S., A.H. McCain, and M.D. Srago. 1973. Control of Botrytis storage rot of giant sequoia seedlings. Plant Disease Reporter 57(1):67-69.

In October 1971, a severe gray mold epidemic, caused by *Botrytis cinerea*, was noted in two nursery beds of 6-month-old *Sequoiadendron giganteum* seedlings at the U.S.F.S. nursery, Placerville, California. Factors contributing to the epidemic were (a) the high susceptibility of giant sequoia seedlings to *Botrytis cinerea;* (b) a lath covering about 10 to 14 inches above the beds which hindered air circulation and maintained high humidities around the seedlings; and (c) the location of these nursery beds in a low, wet area of the field. Because of the possibility of continued infection during seedling storage and shipment, a series of fungicide tests were conducted. Benomyl, either as a pre-lifting field spray or a post-lifting plant dip, gave excellent control of this disease.

14. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

Reviews hosts, damage, life history, and control of various nursery diseases, including damping-off, Fusarium root rot, Sirococcus blight, gray mold, western gall rust, and storage molds.

15. Venn, K. 1981. Winter vigour in *Picea abies* (L.) Karst. VIII. Mouldiness and injury to seedlings during overwinter cold storage. Meddelelser fra Norsk Institutt for Skogforskning 36(5):1-28.

Three-year-old spruce seedlings were inoculated with cold storage fungi before being stored at 0 degrees C. Molds developed extensively during early winter, decreasing later, except on plants lifted very late. Leaf injury was negligible before midwinter, increasing considerably with storage duration, particularly on plants lifted early. Lowest mold infection and leaf injury occurred on plants lifted in late October. Lifting later still resulted in extensive mold and injury. An Austrian provenance was more severely affected than two Norwegian ones. Moldiness was weakly correlated with plant mortality recorded after forcing in spring; leaf injury was more strongly correlated.

Tuberculina Canker
(*Tuberculina maxima*)

Seven articles are included in the bibliography for Tuberculina canker. They all deal with *Tuberculina maxima* on large trees; there are no references for seedlings. The majority of the articles discuss various aspects of the fungus biology, especially the relationship between *T. maxima* and *Cronartium ribicola*, cause of white pine blister rust (3, 4, 5, 6). The remaining three papers (1, 2, 7) are impact or detection reports.

1. Hungerford, R.D. 1977. Natural inactiviation of blister rust cankers on western white pine. Forest Science 23(3):343-350.

Natural inactiviation was assessed for 7 years in a population of over 1,700 *Cronartium ribicola* cankers on *Pinus monticola* at 49 locations. Of lethal-type cankers (those in the bole or expected to reach the bole) that became inactive during the study, around 78 percent remained so. At the end of 7 years, 33 percent of lethal-type cankers were inactive and 12 percent of infected trees were potentially saved because all cankers on them were inactive. Lacking of fruiting by *C. ribicola* and the presence of purple mold (*Tuberculina maxima*) were significantly related to subsequent inactivation. Significant differences in the number of inactive cankers existed between locations.

2. Powell, J.M. 1972. Additional collections of *Tuberculina maxima* on pine stem rusts in western Canada. Canadian Plant Disease Survey 52(4):139.

Reports the first recorded occurrence of *T. maxima* (a) on a pine stem rust in Saskatchewan, where it was found on *Cronartium comptoniae* infecting *Pinus banksiana*, and (b) galls of *Endocronartium harknessii* on *P. contorta* var. *latifolia* in Alberta. *T. maxima* was also found on *C. coleosporioides* cankers on *P. contorta* var. *latifolia* in Alberta at a site 150 miles north of its previously known range.

3. Wicker, E.F. 1979. In vitro dual culture of *Tuberculina maxima* and *Cronartium ribicola*. Phytopathologische Zeitschrift 96(2):185-189.

   There was no evidence of antibiosis, lysis or direct parasitism when the two colonies merged, supporting the view that *T. maxima* is not hyperparasitic on the pine rust.

4. Wicker, E.F. 1980. Biocontrol of conifer stem rusts: the purple mold. Phytopathologia Mediterranea 19:21-26. Rusts of hard pine, proceedings of IUFRO Working Group S2.06.10, edited by H.R. Powers, V. Grasso, P. Raddi. Held September 5-7, 1979, Florence, Italy.

   The use of *Tuberculina maxima* against pine stem rusts in the western United States was evaluated in the *Pinus monticola - Cronartium ribicola* association. The distribution, ecologic amplitude, inoculum production, infectivity, virulence and mode of action of *T. maxima* were established. It shows promise as just a component of integrated control strategies by reducing aeciospore production.

5. Wicker, E.F. 1981. Natural control of white pine blister rust by *Tuberculina maxima*. Phytopathology 71:997-1000.

   An account of the control of *Cronartium ribicola* on *Pinus strobus* by this mold, which reduces the inoculum potential by suppressing production of both pycnia and aecia, and inhibiting canker development.

6. Wicker, E.F. and J.Y. Woo. 1973. Histology of blister rust cankers parasitized by *Tuberculina maxima*. Phytopathologische Zeitschrift 76(4):356-366.

   No evidence was found that *T. maxima*, invading *Pinus monticola* tissues infected by *Cronartium ribicola*, is a hyperparasite. It appears that the enzymatic action of *T. maxima* is directed against the rust infected host cells.

7. Williams, R.E. 1972. Fungi associated with blister rust cankers on western white pine. Dissertation Abstracts 33B(6):2434.

Forty non-uredinaceous species of fungi were isolated from blister rust (*Cronartium ribicola*) cankers on *Pinus monticola*. Two fungi, *Cladosporium cladosporioides* and *Tuberculina maxima*, directly affect rust sporulation and spore dispersal, and occurred with relatively high frequency. They are not considered of value in controlling blister rust except for indirect effects on canker inactivation. Thirteen fungus species caused or were associated with canker necrosis, of which five may be suitable as biological control agents of blister rust.

Upper Stem Canker

(*Fusarium roseum, Phoma eupyrena*)

Only eight papers exist on upper stem canker because it is a disease of recent discovery. All of the papers describe this problem in Pacific Northwest nurseries. The hosts include Douglas-fir, some true firs, and ponderosa pine. Six of the papers deal with detection and biology (1, 2, 4, 5, 6, 7), one with chemical control (3), and one with management strategies (8).

1. Anonymous. 1985. Nursery pathology research project. Oregon State University Forest Research Laboratory, Nursery Technology Cooperative, Annual Report 1984-85, p.11-12.

After 2 years of detailed disease monitoring, some aspects of the top blight disease complex of Douglas-fir have been clarified. Pathogens involved include *Fusarium oxysporum* on hypocotyls, *Phoma eupyrena* and *Fusarium roseum* on the upper stem, and *P. eupyrena, F. roseum* and *Phoma pomorum* on the lower stem during the first year, and *Phomopsis* near the base of new growth in the second year. All fungi involved are soil inhabitants, spread by rain and soil movement; therefore soil management will be a key part of any successful control.

2. Bega, R.V. 1984. Factors contributing to a severe root-aerial disease complex at a large conifer nursery. IN: Western International Forest Disease Work Conference, Proceedings, 32:67-68.

   The Forest Service Humboldt Nursery is suffering large losses of *Pseudotsuga menziesii, Abies magnifica, A. concolor* and *P. ponderosa* seedlings. Isolation of organisms was attempted from diseased seedlings which were stunted, somewhat chlorotic, with a severely restricted root system, numerous rootlet lesions and some stem and needle lesions. The most consistently isolated organisms were *Fusarium oxysporum, Pythium,* and *Phoma.*

3. Cooley, S.J. and A. Kanaskie. 1986. Evaluation of seven fungicides to control canker diseases of bare-root Douglas-fir in Pacific Northwest nursery. USDA Forest Service, Pacific Northwest Region, Report R6-86-14.

   The fungicides Benlate®, Captan®, Chipco 26019®, Daconil 2787®, Difolatan®, Mertect®, and Zyban® were applied periodically at five nurseries in Oregon and Washington for control of Douglas-fir canker diseases. Hypocotyl rot, resulting from ground-line infections by *Fusarium oxysporum,* was reduced by Benlate® at two nurseries; the other fungicides were less effective. Upper stem infections resulting in top mortality were caused primarily by *Phoma* spp. and *Fusarium* spp. and occurred in October and early November. In two nurseries which experience relatively high levels of upper stem canker, all fungicides significantly reduced cankering. Lower stem cankers, seen in spring and summer of the second year, were not controlled by fungicides if cankers were at groundline; good control was achieved with Daconil® and Difolatan® when cankers were higher on the stem and not covered with a soil collar. Cankers caused by *Botrytis* were prevalent in the summer and fall of the second year at one nursery; all fungicides gave effective control, although Daconil® and Difolatan® were superior.

4. Hamm, P.B. and E.M. Hansen. 1987. Stem canker disease of Douglas-fir in nurseries. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.106-108. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

Diseases that kill above-ground portions of Douglas-fir, formerly called "top blight", are listed. Disease recognition, time of infection, infection site, and causal agents are described.

5. Hamm, P.B., E.M. Hansen, and A.M. Kanaskie. 1985. Symptomology of the "top blight", diseases of Douglas-fir bare-root seedlings in nurseries in the Pacific Northwest. Phytopathology 75(11):1367.

Top blight, an ill-defined syndrome, describes at least three distinct periods of mortality. In mid-summer, when seedlings are 3 months old, a hypocotyl rot occurs at or just above the soil line. Seedling tops quickly turn brown while roots are not discolored. *Fusarium oxysporum* is isolated. From September through November, cankers, centered on bark fissures, lateral or terminal shoots, or needle scars, appear between the midstem and seedling apex. *F. roseum* and *Phoma eupyrena* are recovered. A third type of symptom, December through May, is associated with soil collars built up by irrigation and splashing rain. Seedlings are girdled at or above the cotyledon scar, with top symptoms sometimes not evident until new growth suddenly wilts during the spring. *F. roseum* and *P. eupyrena* are most frequently isolated from diseased seedlings.

6. Hansen, E.M. and P.B. Hamm. 1988. Canker diseases of Douglas-fir seedlings in Oregon and Washington bareroot nurseries. Canadian Journal of Forestry Research (In Press).

Canker disease in northwestern forest nurseries have been referred to collectively as "top blight." To distinguish among the various symptoms and their associated fungi, we made systematic observations of and isolations from *Pseudotsuga menziesii* seedlings through two crop cycles in four northwest-

ern nurseries, and suspect fungi were subjected to pathogenicity testing. Five diseases were distinguished. Hypocotyl rot, caused by *Fusarium oxysporum*, kills seedlings during their first growing season. Upper stem canker, caused by *Phoma eupyrena* and *Fusarium roseum*, girdles seedlings in mid-stem in the fall of their first year. Lower stem canker, also caused by *P. eupyrena* and *F. roseum*, kills seedlings in the winter or early spring of their second year and is associated with soil collars built up by splashing water. *Botrytis* and *Phomopsis* cankers occasionally kill new shoots during the second year. Not all diseases are damaging every year or in every nursery.

7. James, R.L. and P.B. Hamm. 1985. Chlamydospore-producing species of *Phoma* from conifer seedlings in Pacific Northwest forest tree nurseries. Montana Academy of Science, Proceedings, 45:26-36.

   Three species of *Phoma* that produce chlamydospores in culture are frequently isolated from diseased conifer seedlings from several Pacific Northwest nurseries. These include *P. eupyrena*, *P. glomerata*, and *P. pomorum*. Major differentiating characteristics of these species include abundance and morphology of chlamydospores, growth habit in culture, conidial exudate color and conidial pigmentation, shape, septation, and size. Cultural characteristics of these three *Phoma* species and a brief description of their habit in nature are discussed.

8. Kanaskie, A. 1987. Management of the top blight disease complex. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.115-121. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

   The "top blight disease complex" refers to five separate but related diseases affecting above-ground portions of bareroot Douglas-fir seedlings. Disease losses can be reduced by altering cultural practices or applying fungicides. This paper provides practical approaches and techniques for reducing losses from top blight.

Western Gall Rust
(*Endocronartium harknessii*)

There are 11 references listed for western gall rust. Only one reference is directly applicable to Pacific Northwest nurseries (8). The typical hosts are ponderosa and lodgepole pine. Most of the references deal with pest detection and impact on the host (1, 2, 3, 6, 10). Several explain aspects of the biology (5, 7, 8, 11) and two discuss management strategies (4, 9). Two references (9, 11) are excellent sources for further citations about western gall rust. No papers focusing directly on control were found.

1. Hiratsuka, Y. 1981. Western gall rust *Endocronarium harknessii* infections of nursery origin on jack pine in Manitoba. Canadian Forestry Service, Northern Forest Research Centre, Forest Management Note No. 5.

During a preliminary pest survey of plantations in the prairie provinces, western gall rust infections were observed in a plantation in Manitoba. Close examination revealed that about 10 percent of the seedlings were infected with western gall rust at the base of the main stems. Samples of the galls indicated that the infections had originated in the nursery that produced the seedlings. Furthermore, two seedlings that exhibited yellowing of needles and poor growth were found to have infections below the soil line, supporting the contention that the infections occurred before planting. The presence of a significant amount of western gall rust at the Pineland Nursery, where the seedlings for the plantations originated, had been reported nearly 10 years earlier.

2. Landis, T.D. and D.W. Johnson. 1977. Examination of Bessey nursery stock for western gall rust. USDA Forest Service, Rocky Mountain Region, Forest Insect and Disease Management, Biological Evaluation R2-77-1.

During 1971, the decision was made to periodically sample ponderosa pine seedlings from the USDA Forest Service Bessey Nursery, located in Halsey, Nebraska, for the presence of

Endocronartium harknessii. As early as 1963, infection of the nursery stock had been noticed, and there was concern that the rust might be inadvertently spread to other areas of the region through outplantings of infected nursery-grown seedlings. Results of the samples to date indicate that gall rust incidence is low on ponderosa pine seedlings from the nursery. If a conscientious effort is made to rogue out rust galls around the nursery, the inoculum level should not build up to damaging levels.

3. Peterson, R.S. 1960. Western gall rust on hard pines. USDA Forest Service, Forest Pest Leaflet 50.

   Reviews effect, ecology, and control of *Peridermium (Endocronartium) harknessii.*

4. Peterson, G.W. and R.A. Read. 1977. Epidemiology of western gall rust in ponderosa pine provenance plantings in southcentral Nebraska. American Phytopathological Society, Proceedings, 4:110.

   The incidence of infection by western gall rust was studied in two experimental plantings of 2-1 *Pinus ponderosa* of 80 provenances established in 1968. In 1973, a rust gall was found near the soil surface on one tree, indicating that infection had occurred in the nursery; annual examinations up to 1977 showed a total of 20 such trees. Altogether, a total of 879 infected trees was detected, 58 percent and 76 percent within 26 and 38 m respectively of the original 20 trees, and 53 percent infected in 1973.

5. Peterson, G.W. and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. USDA Forest Service, Agriculture Handbook 470.

   Discusses hosts, symptoms, damage, life cycles, distribution of pathogens, and methods for control for 31 diseases of seedlings in forest nurseries, including western gall rust.

6. Powell, J.M. and Y. Hiratsuka. 1973. Serious damage caused by stalactiform blister rust and western gall rust to a lodgepole pine plantation in central Alberta. Canadian Plant Disease Survey 53(2):67-71.

The rusts, *Cronartium coleosporioides* and *Endocronartium harknessii* respectively, caused severe damage to *Pinus contorta* var. *latifolia* grown for Christmas trees and ornamental trees in a farm in central Alberta. *C. coleosporioides* killed greater than 80 percent of the young trees in the nursery area and one-third of the transplanted stock in one area. Numerous new galls of *E. harknessii* appeared in autumn 1972 having originated from 1971 infections. A survey showed that 63 percent of the 6- to 12-year-old trees were infected with an average of 28 galls per tree. The damage caused severe financial loss.

7. Riffle, J.W. and G.W. Peterson. 1986. Diseases of trees in the Great Plains. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-129.

Discusses hosts, distribution, symptoms and signs, disease cycle, damage and control of a variety of diseases, including Dothistroma blight of pines, Sirococcus shoot blight, and western gall rust.

8. Sutherland, J.R. and E. Van Eerden. 1980. Disease and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

Reviews hosts, damage, life history, and control of various nursery diseases, including damping-off, Fusarium root rot, Sirococcus blight, gray mold, western gall rust, and storage molds.

9. Tetu-Bernier, P., E. Allen and Y. Hiratsuka. 1983. Bibliography of western gall rust. Canadian Forestry Service, Northern Forest Research Centre, Information Report NOR-X-250.

A comprehensive list of published reports on western gall rust, *Endocronartium (Peridermium) harknessii*, is presented.

10. Thomas, C.S., J.H. Hart and C.E. Cress. 1984. Severity of *Endocronartium harknessii* in two provenance stands of *Pinus ponderosa* in Michigan. Plant Disease 68(8):681-683.

    Transplants (2-1 stock) representing 73 seed sources of *P. ponderosa* were planted at 2 sites 74 km apart in 1968 in southwest Michigan. Previously 0.5 percent or less of the stock had become infected by *Endocronartium harknessii* at a Nebraska nursery. In 1982, disease severity (number of galls per tree) was recorded for each tree and mapped. *P. ponderosa* var. *scopulorum* was more severely diseased than *P. ponderosa* var. *ponderosa*. Within var. *scopulorum*, two southern ecotypes, Colorado Plains and Southern Rockies, were more severely diseased than others. Resistant and susceptible seed sources occurred within ecotypes of both varieties.

11. Ziller, W.G. 1974. *Endocronatrium harknessii*. IN: Tree rusts of western Canada, edited by W.G. Ziller. Canadian Forestry Service, Publication 1329.

    The tree diseases of western Canada caused by rust fungi (Uredinales) are reviewed. Botanical keys and taxonomic descriptions are presented to distinguish between the 70 tree rusts that are known to occur in western Canada. The life cycles of most of these rusts are outlined and illustrated by 21 "spiral" life cycle diagrams. Notes on damage caused, epidemiology and methods of control, as well as a complete list of native hosts and worldwide geographic distribution, are given for each rust. A glossary of 308 technical terms and 157 photographs and photomicrographs are included to facilitate preliminary identification of the rusts; 272 literature references lead to more detailed information on specific aspects of uredinology. Western gall rust is best controlled by elimination of infected trees (pines) near the nursery.

Annotated Bibliography
Insects

Insects

General References

We list eight general insect references in this bibliography. Four of these are compendiums, giving descriptions of insects, hosts, geographical distribution, damage, and management for a number of different seedling insects (1, 2, 3, 8). The reference by Shrimpton (5) describes the biology and management of several conifer nursery insects in great detail. General management is discussed in the article by Sutherland (7); a key to conifer seedling insects is presented by Solomonson (6); and a summary of the impact by nursery pests in the U.S. is reported by Oak (4).

1. Furniss, R.L. and V.M. Carolin. 1977. Western forest insects. USDA, Miscellaneous Publication 1339.

   Describes forest insects of importance in the West, including their range, hosts, food habits and damage.

2. Ives, W.G.H. and H.R. Wong. 1988. Tree and shrub insects of the prairie provinces. Information report NOR-X-292. Northern Forestry Centre, Canadian Forestry Service, Edmonton, Alberta, Canada.

   Discusses hosts and damage and includes color photos for various insects, including wooly adelgids, pine needle scale, root weevils, and cranberry girdler.

3. Johnson, W.T. and H.H. Lyon. 1976. Insects that feed on trees and shrubs: an illustrated practical guide. Cornell University Press.

   Discusses life cycles and hosts and includes numerous color photos of various insects, including *Chionaspis pinifoliae, Adelges cooleyi, Pineus strobi,* and *Otiorhynchus* spp.

4. Oak, S.W. 1985. Nursery pests: pests may cause 20 percent of seedling mortality. IN: USDA Forest Service, General Technical Report WO-46, p.64-75. Insect and disease conditions in the U.S. 1979-83.

Summarizes impacts of pests in U.S. forest nurseries. Impact is reported by states. Hosts mentioned in the discussion include lodgepole and ponderosa pines. Insect damage is reported for cranberry girdler, cutworm, and aphids.

5. Shrimpton, G.W. 1983. Biology and control of some insect pests in B.C. Forest Service seedlings nurseries. M.S. Thesis, Simon Fraser University.

The paper represents the first phase in developing an integrated pest management system for insect pests in British Columbia conifer seedling nurseries. Five important pests, species or groups are covered: cutworms (Lepidoptera: Noctuidae); the European marsh crane fly, *Tipula paludosa*; the cranberry girdler, *Chrysoteuchia topiaria*; small flies (Diptera) in container facilities; and the strawberry root weevil, *Otiorhynchus-ovatus*. The general pest status, life history, damage and occurrence of these pests in B.C. Forest Service nurseries particularly in the last two years is discussed. Several monitoring programs, including pheromone trapping for cutworms and the cranberry girdler and trap boards for weevils, are described and related to decisions on chemical control procedures, as well as cultural and natural controls.

6. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest nurseries. Industrial Forestry Association.

Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruces.

7. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries IN: Forest nursery manual: production of bareroot seedlings, p.203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

   A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

8. Sutherland, J.R. and E. Van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

   Reviews hosts, damage, life history, and control of various nursery insects, including cutworms, marsh crane fly, root and vine weevils, and aphids.

Aphids

(Family Aphididae)

We list 17 references on conifer aphids, 7 dealing specifically with aphids in the Pacific Northwest (1, 9, 12, 13, 15, 16, 17). The remaining were from other parts of the world and the Southeastern United States (4, 6). Aphids attack a number of hosts including Douglas-fir, lodgepole pine, ponderosa pine, and Engelmann spruce. The majority of the references describe the occurrence and impact of the pest on a host plant (3, 4, 5, 7, 9, 13, 14). Three papers explain the use of soaps (1, 11) in controlling aphids; one describes chemical control (6); two discuss natural enemies (14, 17); four describe general management strategies (2, 12, 15, 16); and three refer to the biology of the aphids (8, 10, 17).

1. Anonymous. 1981. Soaps making a comeback on pest control scene. Canadian Forestry Service, Pacific Forest Research Centre, Information Forestry 8(1):6-8.

Dr. George Puritch is studying the use of fatty acids for insect and disease control. Aphids, earwigs, mealybugs, mites and white flies and well as several disease organisms have been controlled by applications of soap. Research is being done on fungicidal soap which will control root rots and *Botrytis*.

2. Carter, C.I. 1975. Towards integrated control of tree aphids. Forestry Commission (Great Britain), Forest Record 104.

Aphid life cycles are of many different types involving one or more annual migration periods which may or may not be associated with an alteration between different kinds of host plant. Some species seriously reduce or disfigure tree growth and need to be controlled. Others use trees mainly as a place to overwinter and then feed for a relatively short period in the spring before dispersing. Precise timing of insecticidal applications is shown to be essential in order to achieve control of aphids. The effect of an insecticidal treatment against aphids is transitory because of the periodic immigration of winged aphids. The whole range of control techniques, whether chemical, ecological or managerial, must be examined and integrated to assure effective control.

3. Carter, C.I. and J.F.A. Nichols. 1985. Host plant susceptibility and choice by conifer aphids. IN: Forestry Commission (Great Britain), Research and Development Paper 135, p.94-99. Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests, proceedings of IUFRO conference, S2.07.06, edited by D. Bevan and J.T. Stoakley. Held September 1-7, 1980, Dornoch, Scotland.

Assessments of *Elatobium abietinum* infestations in Britain have shown that certain species and varieties of *Picea* are more prone to attack and support a higher aphid development rate than others. Two other kinds of aphid, also found on *Picea*, have a different grouping of species that they attack. Among the

aphids that dwell on conifers, it can be seen that both physical and biochemical qualities of the plant determine susceptibility and choice.

4. Fox, R.C. and K.H. Griffith. 1977. Pine seedling growth loss caused by cinaran aphids in South Carolina. Journal of the Georgia Entomological Society 12(1):29-34.

   Pine aphids (*Cinara atlantica* with some *C. watsoni*) were transferred from the field to greenhouse-grown *Pinus taeda* seedlings 1 to 3 years old. Aphid populations on the seedlings after 14 to 22 weeks increased with seedling age and significantly reduced the diameter and height increments of 3-year-old seedlings, showing a preference for vigorous seedlings. It is concluded that pine aphids cause considerable increment losses in the field.

5. Holopainen, J.K. and S. Soikkeli. 1984. Occurrence of *Cinara pini* (Homoptera, Lachnidae) in Scots pine (*Pinus sylvestris*) seedlings with disturbed growth. Annales Entomologici Fennici 50(4):108-110.

   Infestation by *Cinara pini* was found in a plantation of *Pinus sylvestris* in central Finland, where poorly developed terminal buds indicated that the growth of the seedlings was disturbed. Infestation averaged 11 percent among seedlings with normal appearance and 49 percent among those with disturbed growth; 37 percent of the seedlings inspected had disturbed growth. Worker ants, mainly *Formica rufa*, were found in attendance in 96 percent of the aphid colonies. The concentrations of the most important mineral nutrients did not differ between seedlings with normal and disturbed growth, and it is suggested that *C. pini* may be the vector of a virus disease that disturbs the growth of pine seedlings.

6. Hood, W.M. and R.C. Fox. 1980. Control of aphids on loblolly pine in northwestern South Carolina. Journal of the Georgia Entomological Society 15(1):105-108.

   The effectiveness of soil treatments with granules of aldicarb, carbofuran, and disulfoton below the tree dripline in spring or

autumn for the control of the aphids *Cinara atlantica* and *Essigella pini* on *Pinus taeda* 11 to 15 years old was evaluated in field tests in northwestern South Carolina in 1976-77. Aphid populations were monitored weekly for 13 months following the initial application of insecticide. Trees receiving an early application of disulfoton or a late application of aldicarb or carbofuran had significantly fewer examples of *E. pini* than did untreated control trees. No significant differences were found between the different rates of insecticide applications.

7. Hutacharen, C. 1980. A new technique for estimating the population of pine aphids (*Cinara piniformosanus* Takah). Thai Journal of Agricultural Science 13:67-69.

8. Kidd, N.A.C. and D.J. Tozer. 1985. Distribution, survival and hatching of overwintering eggs in the large pine aphid, *Cinara pinea* (Mordv.) (Hom., Lachnidae). Zeitschrift fur Angewandte Entomologie 100(1):17-23.

   The pine aphid, *Cinara pinea*, overwinters as eggs situated on the current year's needles of *Pinus* species, especially *P. sylvestris*. The eggs are sparsely distributed, with shoots seldom having more than one needle bearing one or two eggs. Nevertheless, the eggs were found to be aggregated with respect to both shoots and needles. Egg mortality was estimated (by three different methods) to be about 50 percent between oviposition and hatching, with no evidence of density-dependence. Hatching success in the laboratory increased with longer photoperiods and lower temperatures, while the rate of egg development after diapause increased with temperature. It is suggested that diapause is broken by increasing day length after 22nd December, whereupon egg development and hatching are directly controlled by temperature. Support for this hypothesis is provided by a simulation model which predicts a pattern of egg hatch close to that observed in the field.

9. Oak, S.W. 1985. Nursery pests: pests may cause 20 percent of seedling mortality. IN: USDA Forest Service, General Technical Report WO-46, p.64-75. Insect and disease conditions in the U.S. 1979-83.

Summarizes impacts of pests for U.S. nurseries. Impact is reported by states. Hosts mentioned in the discussion include lodgepole and ponderosa pines. Insect damage is reported for cranberry girdler, cutworm, and aphids.

10. Parry, W.H. 1979. Factors affecting low temperature survival of *Cinara pilicornis* eggs of Sitka spruce. International Journal of Biometeorology 23(3):185-193.

In Scotland, *Elatobium abietinum* overwinters on *Picea sitchensis* as active individuals of all stages, the egg stage being found only rarely in winter. *Cinara pilicornis*, however, overwinters as eggs under identical winter conditions and often on the same tree as *E. abietinum*. The results are presented of studies to investigate the supercooling abilities of the egg stage of *C. pilicornis* in order to compare these with those of active overwintering forms and to relate this ability to changes in polyhydric alcohol levels, temperatures and the diapausal stage of the eggs. Oviparous females of *C. pilicornis* deposited eggs in October and early November and the dry weight, but not the fresh weight, decreased during winter. Diapause terminated in early March, the eggs hatching in early May. Mean egg supercooling points varied during the winter, the variation being related to the temperature in the period preceding the collection of the samples. Both glycerol and mannitol were isolated from the eggs. Mannitol levels decreased to zero by mid-winter, the levels increasing after diapause termination. Glycerol levels increased up to diapause termination and thereafter decreased, none of the compound being present just prior to egg hatch. Neither glycerol or mannitol were related to supercooling ability, the variation being related to low temperatures that possibly induced changes in the levels of an unknown factor.

11. Parry, W.H. and R. Rose. 1983. The role of fatty acids and soaps in aphid control on conifers. Zeitschrift fur Angewandte Entomologie 96(1):16-23.

Experiments were carried out in Scotland to determine the toxicity of various fatty acids and their potassium salts to two aphid pests of conifers, namely *Elatobium abietinum*, which was kept on potted Sitka spruce under outdoor conditions and subsequently brought into the laboratory, and *Adelges cooleyi* brought into the laboratory on shoots of Douglas-fir; the toxic effects on their coccinellid predator *Aphidecta obliterata* were also tested. Both the fatty acids and potassium soaps possessed comparable toxicity to *E. abietinum*, the LC50s ranging from around 0.1 to above 10 percent. Most fatty acids remained in suspension for a short time only, while soaps with a carbon chain greater than 14 tended to gelate. This minimized the potential of both agents under field conditions. Since larvae of *A. obliterata* were more susceptible than adults to several of the soaps, their application during larval development of the predator should be avoided. With the exception of potassium oleate, LC50s for *A. cooleyi* in the laboratory were lower than the field values because of the masking effect of foliage. The saturated soaps potassium caproate, caprylate, caprate and laurate possessed satisfactory toxic and spraying characteristics, but were marginally inferior to the unsaturated potassium oleate and lineolate in both respects.

12. Shrimpton, G. 1985. Four insect pests of conifer nurseries. USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.119-121. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

Four pests of conifer nurseries in British Columbia, the strawberry root weevil, tarnished plant bug, European marsh crane fly, and conifer root aphid, are described. Their general pest status, occurrence in the nurseries, life history, damage, and control are briefly discussed.

13. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest nurseries. Industrial Forestry Association.

Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruces.

14. Stary, P. 1976. *Cinara piceae* (Panz.) (Hom., Lachnidae), a pest of young European fir trees (*Abies alba* Mill.), and its natural enemy complex in Czechoslovakia. Studia Entomologica Forestalia 2(10):171-180.

Cinara piceae is reported infesting 5- to 7-year-old trees in a field nursery in 1971, apparently causing vertical fissures in the stem bark. Five species of natural enemies were observed, the most important being the syrphid predator *Didea fasciata.*

15. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p.203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

16. Sutherland, J.R. and E. Van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

    Reviews hosts, damage, life history, and control of various nursery insects, including cutworms, marsh crane fly, root and vine weevils, and aphids.

17. Tilles, D.A. and D.L. Wood. 1982. The influence of carpenter ant (*Camponotus modoc*) (Hymenoptera: Formicidae) attendance on the development and survival of aphids (*Cinara* spp.) (Homoptera: Aphididae) in a giant sequoia forest. Canadian Entomologist 114(12):1133-1142.

    Camponotus modoc was associated with numerous species of Homoptera in a mixed coniferous forest at Giant Forest, Sequoia, California, in 1975-77. Ant-exclusion experiments and field observations indicated that the survival of the abundant *Cinara occidentalis* on *Abies concolor* depended on attendance by *Camponotus modoc*. More of the predators *Myzia oblongoguttata, Deraeocoris brevis, Passaloecus cuspidatus* and *Pityohyphantes* spp. were found on ant-unattended than on attended aphid colonies. As aphid populations decreased, ant attendance per aphid and the number of predators per aphid increased. Attended aphid colonies were more likely than unattended ones to survive to produce oviparae and a lower proportion of alates.

Cooley Spruce Gall Aphid

(*Adelges cooleyi*)

We include 24 references on Cooley spruce gall aphid; 12 of these describe some aspect of the occurrence of the insect in the Pacific Northwest (2, 4, 6, 9, 10, 11, 12, 20, 21, 22, 23, 24). This insect affects only Douglas-fir and spruce. Over half of the papers deal with the biology of the pest (7, 14, 15, 16, 17, 18) or management of it through the use of chemicals (1, 3, 9, 10, 11, 13, 21) or soaps (19). Seven papers describe general management strategies (2,4, 5, 20, 22, 23, 24); two describe management through cultural activities (6,) 12; and one discusses pest detection methods (8). Only one article mentions biological control of the insect (5).

1. Ahrens, J.F. 1980. Cooley spruce gall aphid control in Christmas tree plantings with aldicarb, Windsor, Connecticut, 1977-79. Insecticide and Acaricide Tests 5:203-204.

Cooley spruce gall aphids on Douglas-fir reduce growth rates and quality for Christmas trees. Granular aldicarb was applied at the rate of 10 grams per tree in single bar holes 4 to 6 inches deep in the drip line of the plantation. Treatment was repeated in the following two years. Moderate infestations occurred on control trees and zero to slight infestations occurred on treated trees.

2. Antonelli, A.L. and R.L. Campbell. 1981. Cooley spruce gall aphid. Washington State University, Cooperative Extension Service, Extension Bulletin 966.

Summarizes life history, description, damage, and control of *Adelges cooleyi.*

3. Campbell, R.L. and C.P. Balderston. 1972. Insecticidal control of *Adelges cooleyi* on Douglas-fir in Ohio, with notes on biology. Journal of Economic Entomology 65(3):912-914.

Discusses the life cycle of *Adelges cooleyi* on the alternate hosts *Pseudotsuga menziesii* and *Picea* spp. The aphid can continue indefinitely as progredientes or sistentes on *Pseudotsuga menziesii;* in the summer of 1968, in northeastern Ohio, there may have been as many as six generations on this host. Interim results are given of trials in chemical control, using 11 different insecticides. The carbamates used (carbaryl, phoxim, and aldicarb) seem to have been the most effective.

4. Capizzi, J. 1976. Insect problems on narrow-leaved evergreens. Ornamentals Northwest: 1-7:1-2.

Briefly reviews the damage, lifecycle, and control of Cooley spruce gall aphid, and scale insects on pine and Douglas-fir needle midge.

5. Crooke, M. 1960. *Adelges cooleyi*: an insect pest of Douglas-fir and Sitka spruce. Forestry Commission (Great Britain), Leaflet 2.

   Discusses life cycle, indications of attack, damage caused, natural enemies, and control measures for *Adelges cooleyi*.

6. Johnson, J.M., M.P. Little, and R.I. Gara. 1977. Effects of different N-fertilizers and concentrations on *Adelges cooleyi* populations. Journal of Economic Entomology 70:527-528.

   Three-year-old Douglas-fir seedling were treated with soil drenches of $(NH_4)_2SO_4$, $NaNO_3$ and urea (also applied as a foliar spray) at low (56 and 112 kg/ha) and at high (224 and 448 kg/ha) concentrations. Fewer *Adelges cooleyi* were found on trees with low N-fertilizer concentration and on those treated with $(NH_4)_2SO_4$ compared with other forms of N and controls.

7. Johnson, W.T. and H.H. Lyon. 1976. Insects that feed on trees and shrubs: an illustrated practical guide. Cornell University Press.

   Discusses life cycles and hosts and includes numerous color photos for various insects, including *Chionaspis pinifoliae*, *Adelges cooleyi*, *Pineus strobi*, and *Otiorhynchus* spp.

8. Lasota, J.A. and D.J. Shetlar. 1986. Assessing seasonal and spatial abundance of *Adelges cooleyi* (Gillette) (Homoptera: Adelgidae) by various sampling techniques. Environmental Entomology 15(2):254-257.

   The efficiency of four different sampling methods in assessing seasonal and spatial distributions of the adelgid *Adelges cooleyi* on *Pseudotsuga menziesii* was determined in Pennsylvania in 1979. Counts of *A. cooleyi* were consistently greater on the upper two-thirds of trees throughout the season. Early summer populations were higher on the northern and eastern aspects of trees, but became more evenly distributed as summer progressed. All four sampling techniques were relatively consistent at the various sampling periods. The 3-min count recorded the largest number of adelgids and was most accurate in assessing late season, declining populations.

9. Miller, G.E. 1982. Phytotoxicity of Dimethoate 4E® to Douglas-fir in seed orchards. Canadian Forestry Service, Research Notes 2(2):7-8.

Dimethoate is the only insecticide registered for use against cone and seed insects on Douglas-fir in Canada; it is used at concentrations of 0.5 to 1.0 percent and applied as a foliar spray until run-off. Treatments at 0.5 percent in three seed orchards in British Columbia in 1979 and 1980 at the end of April and beginning of May led to unexpected levels of phytotoxicity. Some trees were moderately burned (about 50 percent of needles turning red) and some were severely burned (all needles turned red); virtually all the burned needles fell off the trees within 3 weeks of treatment. The degree of needle burn was correlated with clone or family, and one clone was susceptible at two orchard sites and at the same site in 2 years. Some genetic control over sensitivity was indicated. Only two severely burned trees died; the others survived because the vegetative buds flushed 1 to 2 weeks after the application of dimethoate. It is suggested that the application of dimethoate after vegetative flush for the control of *Adelges cooleyi* could result in considerable mortality of trees in sensitive clones or families.

10. Mitchell, R.G. and J. Neisess. 1977. Field test of acephate against two Douglas-fir Christmas tree pests. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-302.

Sample *Pseudotsuga menziesii* in a 6-year-old plantation in Oregon were treated with 0.05, 0.1 and 0.2 lb/gal of acephate either before bud burst or when 60 percent of trees had flushed, to control the needle midge *Contarinia pseudotsugae* and the spruce gall aphid *Adelges cooleyi*. Acephate reduced midge populations, particularly when applied before bud burst; there was a significant reduction in populations with increasing dose. Acephate was not effective against the spring generation of the gall aphid and the winter population 1 year after treatment was significantly greater than on untreated trees. Some needles of trees that had flushed before treatment were damaged at all doses; 10 to 50 percent were damaged by the highest dose and less than 1 percent by the lowest dose. Trees treated

with the highest dose before bud burst also developed yellowing of the needles..

11. Mitchell, R.G. and J. Neisess. 1979. Aerial treatment of a Douglas-fir needle midge with acephate. Journal of Economic Entomology 72:447-449.

    Acephate (0.56 and 1.12 kg/ha a.i.) and the registered midge control agent endosulfan (2.24 kg/ha a.i.) were aerially applied 2 weeks before bud burst (acephate only), and at bud burst, to a Christmas tree plantation infested with Douglas-fir needle midge (*Contarinia pseudotsugae*) in Oregon in 1977. Midge populations were n.s.d. between early and late acephate applications, between acephate dosages, or between endosulfan and late acephate treatments; all were significantly lower than controls. Aphid (*Adelges cooleyi*) populations were n.s.d. between the various acephate treatments and controls but the population on the endosulfan plot was significantly smaller than those on late-treated acephate plots and controls.

12. Mitchell, R.G. and H.G. Paul. 1974. Field fertilization of Douglas-fir and its effect on *Adelges cooleyi* populations. Environmental Entomology 3(3):501-504.

    Population levels of *Adelges cooleyi* (Gillette) were evaluated for 2 years on 7-year-old Douglas-fir trees after fertilization with three forms of nitrogen. Aphid fecundity on trees individually treated with equivalents of 50 and 200 lb N/acre (56 and 224 kg N/ha) was 11 to 42 percent higher than on untreated trees in the first year of study and dropped to normal in the second year. Winter survival of the aphid was 10 to 20 percent higher than normal on fertilized trees in both years. In the same period, aphid establishment appeared to be reduced on fertilized trees. Two years after fertilization, the population levels were essentially the same on treated and untreated trees.

13. Nielsen, D.G. and C.P. Balderston. 1977. Control of eastern spruce and Cooley spruce gall aphids with soil-applied systemic insecticides. Journal of Economic Entomology 70:205-208.

    Application of granular systemic insecticides in mid-April to the soil around *Picea abies* and *P. glauca* in an arboretum at

Wooster, Ohio, prevented the formation of galls by *Adelges abietis*. The same insecticides applied in mid-May or mid-June did not prevent gall formation or cause mortality of adelgids within galls. Aldicarb controlled *A. abietis* when applied to broken ground at the dripline of the tree at a rate of 2.8 g a.i. per inch of stem diameter at 1 foot above ground; carbofuran and Dacamoxx® were effective only when applied at 5 times this rate. Aldicarb and carbofuran were similarly effective against *Adelges cooleyi*.

14. Parry, W.H. 1977. The settling behaviour of *Adelges cooleyi* (Gilletteella cooleyi) sistentes on mature needles of Douglas-fir. Zeitschrift fur Angewandte Entomologie 82(4):359-372.

Early-hatching sistentes migrate to the opening buds, where they settle, and late-hatching ones remain on the older needles and enter diapause. Two periods of redistribution occurred on material collected in 1973-74 from a plantation in Aberdeenshire: the first in the short time between egg hatching and diapause, and the second during mild weather in winter after the termination of diapause. Movement of sistentes to previously uninfected needles and needle upper surfaces was correlated with density and enabled insects to colonize the needle cortex with less competition from neighbors. On the lower surface, the insects probed through the stomata, while on the upper surface most settled in the median groove, thus having to probe through the epidermis and the subepidermal sclerotized cells. Despite this difference in penetration, there was no difference in the rate of development and egg production.

15. Parry, W.H. 1978. Studies on the factors affecting the population levels of *Adelges cooleyi* (Gillette) (*Gilletteella cooleyi*) on Douglas-fir. 1. Sistentes on mature needles. Zeitschrift fur Angewandte Entomologie 85(4):365-378.

Life tables for sistentes on 1971 needles in north Scotland, over their life span of 6 years, were compared with those on needles in their second year over the same period. Overwintering mortality was identified as the key factor controlling changes in mortality in both cases. Other mortality factors, particularly variation in natality and establishment loss before diapause,

were of greater importance on second-year needles than 1971 needles. The possibility of induction of physiological change in the food plant by large populations of sistentes and their adaptations to winter survival are discussed.

16. Parry, W.H. 1978. Studies on the factors affecting the population levels of *Adelges cooleyi* (Gillette) (Gilletteella cooleyi) on Douglas-fir. 2. Progredientes and sistentes on current year needles. Zeitschrift fur Angewandte Entomologie 86(1):8-18.

    In studies in 1972-76, progrediens nymphs migrated to the newly opening buds in May/June, the vast majority settling and dying without developing. The survivors developed into progrediens apterae or progrediens alatae (sexuparae). The amount of soluble N in current-year needles was high at the time of nymphal immigration, but decreased rapidly thereafter. The total annual mortality of the sistentes developing from eggs laid by the progrediens apterae was largely determined by adult natality.

17. Parry, W.H. 1980. Studies on the factors affecting the population levels of *Adelges cooleyi* (Gillette) on Douglas-fir. 3. Low temperature mortality. Zeitschrift fur Angewandte Entomologie 90(2):133-141.

    Studies were carried out in Scotland in 1977-79 to assess the role of low temperature in the mortality of *Adelges cooleyi* on Douglas-fir during the diapause and post-diapause phases succeeding the summer aestivation period when low temperatures were of not importance. Live sistens proportions were higher in young than in old colonies at the beginning of winter, this being attributed to differential mortality between hatching and the commencement of winter. Mortality rates were similar in both colonies during winter. The ability of overwintering of *A. cooleyi* sistentes to survive temperatures down to -30 degrees C decreased on termination of diapause when sap imbibition commenced. This susceptibility to freezing at temperatures as high as -5 degrees C gradually diminished, but remained much higher than that during diapause. Minimum temperatures recorded in northeast Scotland were insufficient to cause mortality during diapause, but in some years could cause

considerable mortality during the most susceptible immediate postdiapause period.

18. Parry, W.H. and S. Spires. 1982. Studies on the factors affecting the population levels of *Adelges cooleyi* (Gillette) on Douglas-fir. 4. Polymorphism in progredientes. Zeitschrift fur Angewandte Entomologie 94(3):253-263.

    Laboratory and field observations were carried out in Scotland in an attempt to clarify the mechanism controlling alary polymorphism in *Adelges cooleyi*. Developing progredientes settled around the midpoint of newly emerging needles of *Pseudotsuga menziesii*; on some trees, the apterae settled closer to the base than apterae on other trees and alatae on the same tree. Both apterae and alatae inserted their stylets into the phloem cells when feeding. Morph determination was not controlled by any of these factors or by temperature, photoperiod or shoot maturity. In both study areas and in the laboratory, the initial colonization density on new needles was closely related to alate formation. It was thought that high free amino acid levels at the time of morph determination might be an associated factor.

19. Parry, W.H. and R. Rose. 1983. The role of fatty acids and soaps in aphid control on conifers. Zeitschrift fur Angewandte Entomologie 96(1):16-23.

    Experiments were carried out in Scotland to determine the toxicity of various fatty acids and their potassium salts to two aphid pests of conifers, namely *Elatobium abietinum*, which was kept on potted Sitka spruce under outdoor conditions and subsequently brought into the laboratory, and *Adelges cooleyi* brought into the laboratory on shoots of Douglas-fir; the toxic effects on their coccinellid predator *Aphidecta obliterata* were also tested. Both the fatty acids and potassium soaps possessed comparable toxicity to *E. abietinum*, the LC50s ranging from around 0.1 to above 10 percent. Most fatty acids remained in suspension for a short time only, while soaps with a carbon chain greater than 14 tended to gelate. This minimized the potential of both agents under field conditions. Since larvae of *A. obliterata* were more susceptible than adults to several of the soaps, their application during larval development of the

predator should be avoided. With the exception of potassium oleate, LC50s for *A. cooleyi* in the laboratory were lower than the field values because of the masking effect of foliage. The saturated soaps potassium caproate, caprylate, caprate, and laurate possessed satisfactory toxic and spraying characteristics, but were marginally inferior to the unsaturated potassium oleate and lineolate in both respects.

20. Saunders, J.L. 1970. How to control the Cooley spruce gall aphid. Weeds, Trees, Turf 9(1):27.

    This short article discusses control of Cooley spruce gall aphid with respect to the life cycle of the insect. It describes results of control trials in 1967 and 1968 with sprays, soil granules, and bark paints of several pesticides.

21. Saunders, J.L. and D.A. Barstow. 1970. *Adelges cooleyi* (Homoptera: Phylloxeridae) control on Douglas-fir Christmas trees. Journal of Economic Entomology 63:150-151.

    Adelges cooleyi was controlled by high-volume sprays of endosulfan or Baygon®, or by ultra-low-volume application of Baygon®, in infested *Pseudotsuga menziesii* plantations in Washington. Several systemic insecticides also tested were less effective.

22. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest nurseries. Industrial Forestry Association.

    Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruces.

23. Sutherland, J.R. 1984. Pest management in Northwest bareroot nurseries. IN: Forest nursery manual: production of bareroot seedlings, p.203-210. Edited by M.L. Duryea and T.D. Landis, Martinus Nijhoff/Dr W. Junk Publishers.

A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina, Fusarium,* and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

24. Wood, C. 1977. Cooley spruce gall aphid. Canadian Forestry Service, Pacific Forest Research Centre, Pest Leaflet FPL 6.

Reviews hosts, distribution, damage, detection, life history, prevention, and control of *Adelges cooleyi* on spruce and Douglas-fir.

Cranberry Girdler Moth

(*Chrysoteuchia topiaria*)

We list 14 references on cranberry girdler moth; the majority deal the insect in the Pacific Northwest on Douglas-fir and grass. Grass fields next to forest nurseries are the primary source of the adult moth. Three papers deal with some aspect of the insect's biology (1, 2, 8), four with detection and impact on the host (3, 4, 7, 13), one with chemical control (14), and four with general management practices (5, 6, 10, 11). The articles by Shrimpton (9) and Triebwasser and Overhulser (12) cover both biology and management.

1. Kamm, J.A. 1973. Biotic factors that affect sod webworms in grass seed fields in Oregon. Environmental Entomology 2(1):94-96.

An outbreak of *Chrysoteuchia topiaria* was observed through the autumn and winter of 1971 to determine the major biotic factors affecting the overwintering larvae in Oregon grasslands. Predation by various birds in October reduced the larval population in a field of bluegrass (*Poa*) by more than 80 percent. The birds found infestations and picked larvae out of their hibernacula during most of the winter. The fungus *Beauveria bassiana* was present in all field collections, but infected only 3.1 percent of the population; 8.3 percent of the full-fed larvae were parasitized by the *Tachinid Lydina polidoides*. Three species of sod webworms that occur in Oregon grasslands were found to differ in nutritional requirement; *Pediasia trisecta* and *Tehama bonifatella* required leaves for optimum growth, whereas *C. topiaria* grew equally well on either roots or leaves of *Festuca rubra* var. *commutata*. In nature, the larvae of *C. topiaria* remained within the crown of the plant to feed, and are therefore probably less susceptible to contact with foliar applications of insecticide than the larvae of *P. trisecta* and *T. bonifatella*. However, the rate of oviposition of *C. topiaria* suggests that a quick-killing insecticide applied when the adults emerge would prevent the moths from laying most of their eggs.

2. Kamm, J.A. 1973. Mating, fertility, and fecundity of some sod webworms (Lepidoptera: Pyralidae) in the laboratory. Annals of the Entomological Society of America 66(3):692-694.

Several of the Pyralids known as sod webworms have been reared in the laboratory, but not for many generations, and a reduction in fecundity has been reported in one species. Investigation on the frequency of mating, fertility, and fecundity of *Tehama bonifatella* and *Chrysoteuchia topiaria* during the first laboratory generation are recorded. About 80 percent of the females of the first species produced fertile eggs irrespective of the day of mating, but only 40 percent of the females of the other laid fertile eggs when exposed to males on the day of emergence and only 15 percent when mating was postponed until the third day. Delayed mating had no effect on the percentage fertility of the eggs laid. The culture subsequently failed.

3. Kamm, J.A. and L.M. McDonough. 1979. Field tests with the sex pheromone of the cranberry girdler. Environmental Entomology 8(4):773-775.

In four out of five tests in commercial grass seed fields in Oregon, traps baited with 800, 900 or 1,000 mu g of (Z)-11-hexadecenal were as attractive to males of *Chrysoteuchia topiaria* as traps baited with virgin females. The aldehyde was effective in attracting maximum numbers of males only within a narrow range of concentrations; a concentration of 1000 mu g/septum was optimal. (Z)-9-tetradecenyl formate, which has a molecular shape similar to that of the aldehyde, was not attractive to males at the concentrations tested. Varying amounts of (E)-11-hexadecenal in combination with (Z)-11-hexadecenal did not significantly affect trap catches. The (Z)-isomers of 13-hexadecenal, 13-octadecenal and 11-hexadecen-1-ol proved to be potent inhibitors and interfered with normal pheromone communication.

4. Kamm, J.A. and L.M. McDonough. 1982. Seasonal flight of the cranberry girdler determined with pheromone traps. Journal of the New York Entomological Society 90(2):94-98.

Chrysoteuchia topiaria occurs throughout North America in habitats ranging from coastal cranberry bogs to high mountain peaks; the pyralid is polyphagous. The authors describe the seasonal flight period of this moth on the basis of catches over a 3-year period in traps baited with sex pheromone and operated in Oregon in commercial seed fields of Kentucky bluegrass (*Poa pratensis*) or orchardgrass (*Dactylis glomerata*). Pherocon IC traps were baited with natural rubber septa containing 1 mg (2)-11-hexadecenal and 0.05 mg (Z)-9-hexadecenal. Daily trap-catches averaged over 5 days were a better indicator of seasonal flight than single-day catches. The flight peaks occurred at different calendar dates in the different years, but after approximately the same sum of effective daily mean temperatures (averaging 857 degrees C) had been reached. Overwintering pupae were capable of some development at 10 degrees C, and 5.5 degrees C was considered to be the developmental threshold. More than 90 percent of the flight period occurred within 30 to 35 calendar days. Even though pheromone traps measured both flight activity and population density, a combi-

nation of information based on pheromone-trap data and thermal constants provided a reasonable estimate of the seasonal abundance of adults, excluding data obtained during periods of cool rainy weather.

5. Kamm, J.A., P.D. Morgan, D.L. Overhulser, L.M. McDonough, M. Triebwasser, and L.N. Kline. 1983. Management practices for cranberry girdler (Lepidoptera: Pyralidae) in Douglas-fir nursery stock. Journal of Economic Entomology 76:923-926.

Chrysoteuchia topiaria, a known pest of grasses and cranberries, was shown in field-plot studies in Oregon and Washington in 1980-81 to be a pest of seedlings of Douglas-fir grown in nurseries. The pyralid was capable of reproduction in nursery beds where feeding larvae partially or completely girdled the tap-root of seedlings. Pheromone trap collections indicated that grasslands bordering nurseries, and not nursery beds, were the primary source of adults. In addition to Douglas-fir, several species of true fir were damaged by larvae, but no feeding damage was observed on pine, cedar, hemlock, or spruce. Insecticides applied to control adults and larvae effectively reduced the incidence of damage. It was suggested that, when possible, a pest management program should include grasslands bordering the nursery, control of weeds, and the use of a non-food plant cover crop in the nursery.

6. Kamm, J.A. and L.M. McDonough. 1983. Cranberry girdlers eat trees, too. Agricultural Research 31(12):14-15.

Field observations and pheromone-trap monitoring carried out in Oregon showed that adults of *Chrysoteuchia topiaria*, which is a serious pest of cranberries and grasses, migrated into nurseries of Douglas-fir, where eggs were laid and the hatching larvae fed on tap-roots, reducing seedling quality and vigor, and, in some cases, killing the seedlings. This problem could be practically eliminated by applying diazinon to nurseries during the flight period of the pest, usually from mid-June to mid-July, followed by 1 or 2 applications of chlorpyrifos to control any larvae. In addition, wherever possible, grasslands bordering a nursery should be re-seeded to a crop on which *C. topiaria* does not feed, to reduce migration into the nursery, and weeds

should be removed from vacant beds and a non-host cover crop planted.

7. Oak, S.W. 1985. Nursery pests: pests may cause 20 percent of seedling mortality. IN: USDA Forest Service, General Technical Report WO-46, p.64-75. Insect and disease conditions in the U.S. 1979-83.

Summarizes impacts of pests for U.S. nurseries. Impact is reported by states. Hosts mentioned in the discussion include lodgepole and ponderosa pines. Insect damage is reported for cranberry girdler, cutworm, and aphids.

8. Roberts, S.L. and D.L. Mahr. 1986. Development of cranberry girdler, *Chrysoteuchia topiaria* (Lepidoptera: Pyraliadae) in relation to temperature. Great Lakes Entomologist 19(2):85-90.

The development of *Chrysoteuchia topiaria* was studied in controlled-temperature chambers. Estimates of the threshold temperatures for the egg, larval, and prepupal-pupal stages were 9.4, 6.8, and 9.8 degrees C, respectively. An overall threshold temperature for egg to adult development was estimated to be 8.8 degrees C. Degree-day summations above thresholds averaged 107, 484, and 388 for the egg, larval, and prepupal-pupal stages, respectively.

9. Shrimpton, G.W. 1983. Biology and control of some insect pests in B.C. Forest Service seedlings nurseries. M.S. Thesis, Simon Fraser University.

The paper represents the first phase in developing an integrated pest management system for insect pests in British Columbia conifer seedling nurseries. Five important pests, species or groups are covered: cutworms (Lepidoptera: Noctuidae); the European marsh crane fly, *Tipula paludosa*; the cranberry girdler, *Chrysoteuchia topiaria*; small flies (Diptera) in container facilities; and the strawberry root weevil (*Otiorhynchus ovatus*). The general pest status, life history, damage and occurrence of these pests in B.C. Forest Service nurseries particularly in the last two years is discussed. Several monitoring

programs including pheromone trapping for cutworms and the cranberry girdler and trap boards for weevils are described and related to decisions on chemical control procedures, as well as cultural and natural controls.

10. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest forest nurseries. Industrial Forestry Association.

    Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruces.

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    A survey of Northwest bareroot nurseries revealed that root rots (*Macrophomina*, *Fusarium*, and *Phytophthora*) and Sirococcus blight are the major diseases, that the cranberry girdler (*Chrysoteuchia topiaria*) and various aphids are the most important insect pests, and that numerous rodents and seed-eating birds are frequent animal pests. Many site features affect both pest occurrence and successful management. However, the types of pest management practices used depend upon factors including the availability of advice from pest management specialists, the use of surveys, and numerous cultural practices. Nontarget effects of pesticides are also of concern. More information is needed on many aspects of pest management so that nursery managers can grow better seedlings.

12. Triebwasser, M.E. and D.L. Overhulser. 1981. The cranberry girdler (*Chrysoteuchia topiaria*) in conifer nurseries of western Washington and Oregon. IN: USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-109, p.80-83. Intermountain Nurseryman's Association and Western Forest Nursery Association, Proceedings.

The cranberry girdler has been identified as an insect problem in some conifer nurseries. The life history of this insect and means for control are discussed.

13. Tunnock, S. 1982. Cranberry girdler moth damage to Douglas-fir seedlings in Coeur d'Alene Nursery, Idaho Panhandle National Forest, 1982. USDA Forest Service, Northern Region, Report 82-28.

Chrysoteuchia topiaria is destroying bark from root collars of 2-0 Douglas-fir seedlings in the Coeur d'Alene Nursery, Idaho. Samples (14,188 seedlings) from 25 Douglas-fir beds showed damage ranging from 0 to 3.8 percent, with an average of 0.9 percent partially or totally girdled. No pines were attacked. No operational control methods are available. Sprays to kill larvae in the soil or flying adult moths are being tested in other nurseries. Population manipulation with pheromones may be feasible to disrupt mating. A population prediction method needs to be developed.

14. Tunnock, S. 1985. Suppression of cranberry girdler damage in beds of Douglas-fir seedlings, Coeur d'Alene Nursery, Idaho Panhandle National Forest — 1984. USDA Forest Service, Northern Region, Report 85-4.

The cranberry girdler, *Chrysoteuchia topiaria*, has caused increasing damage to tree seedlings in the Coeur d'Alene Nursery since 1980. Heaviest feeding has occurred on the tap roots of 2-0 Douglas-fir stock. By 1983, 8.2 percent of the seedlings examined in seedbeds were injured by this moth. A spray program was adopted in 1984 to reduce the amount of damage. Three applications of Diazinon® at 1 lb. a.i. per acre were used to kill adult moths, and three applications of Dursban® at the same rate were used to reduce larval populations in the soil of

Douglas-fir beds. Results of the insecticidal treatments were determined in November 1984 during lifting operations. In sprayed beds, only 0.01 percent of the 2-0 Douglas-fir seedlings examined were injured, and 0.9 percent of the 3-0 Douglas-firs examined were injured. There were no beds of unsprayed Douglas-fir to use as a check. Because damage was 8.12 percent in beds during 1983, and moth populations were high in 1984, damage in unsprayed beds could have been 8 percent or greater in 1984. Nurseries consider damage tolerable when it is below 1 percent.

Cutworms

(Family Noctuidae)

A total of eight citations on cutworms are listed and, of these, five are pertinent to the Pacific Northwest (1, 2, 6, 7, 8). This insect feeds on conifers as well as many other plants. Several references cover identification and general management strategies (4, 7, 8). Chemical (5) or chemicals in combination with other practices (6) help to control this insect. Two articles describe the impact of cutworms on conifer crops (2, 3).

1. Johansen, C. 1973. How to recognize cutworms, armyworms, and loopers. Pacific Northwest Cooperative Extension Publication PNW 130.

   Descriptions and drawings of the typical mature larvae of the major cutworm, armyworm, and looper pests in the Pacific Northwest.

2. Lindquist, O.H. 1970. Cutworm damage to summer-planted white spruce tubelings. Canadian Forestry Service, Bi-Monthly Research Notes 26(6):56.

   Container-grown *Picea glauca* seedlings outplanted on a burned site were 40 percent destroyed by cutworms within two months. Two species of cutworm were involved, *Pyrrhia exprimens* and *Mamestra curialis*. *P. exprimens* occurs widely across Ontario, but *M. curialis* has been recorded only once previously in Ontario. The origin of the 1967 infestation of cutworms is uncertain, but the burned-over area may have harbored a population of pupae in prolonged diapause which

emerged following the burn, or egg-laden moths from an outside source were attracted to the site of the burn.

3. Oak, S.W. 1985. Nursery pests: pests may cause 20 percent of seedling mortality. IN: USDA Forest Service, General Technical Report WO-46, p.64-75. Insect and disease conditions in the U.S. 1979-83.

   Summarizes impacts of pests for U.S. nurseries. Impact is reported by states. Hosts mentioned in the discussion include lodgepole and ponderosa pines. Insect damage is reported for cranberry girdler, cutworm, and aphids.

4. Palmer, M. and T. Nicholls. 1981. How to identify and control cutworm damage on conifer seedlings. USDA Forest Service, North Central Forest Experiment Station.

   Discusses life cycle, identification and control.

5. Palmer, M.A. and T.H. Nicholls. 1983. Diagnosis and control of cutworm damage on conifer seedlings in nursery seedbeds. Tree Planters' Notes 34(2):20-21.

   Seedling damage to conifers at a nursery in the northern Lake States from the mid-1960's onwards was found to be caused by the dingy cutworm (*Feltia ducens*). Small plots of 1-0 *Pinus resinosa* seedlings were sprayed in June 1979 with Diazinon AG-500® at 4 quarts/96 gal water. The number of seedlings damaged was recorded before treatment and 6 or 12 days later. No damage or cutworms were recorded on treated plots. It was estimated that 1 million trees (valued at $58,000) were saved at this nursery in 1979 by cutworm control.

6. Shrimpton, G.W. 1983. Biology and control of some insect pests in B.C. Forest Service seedlings nurseries. M.S. Thesis, Simon Fraser University.

   The paper represents the first phase in developing an integrated pest management system for insect pests in British

Columbia conifer seedling nurseries. Five important pests, species or groups are covered: cutworms (Lepidoptera: Noctuidae); the European marsh crane fly, *Tipula paludosa*; the cranberry girdler, *Chrysoteuchia topiaria*; small flies (*Diptera*) in container facilities and the strawberry root weevil, *Otiorhynchus ovatus*. The general pest status, life history, damage, and occurrence of these pests in B.C. Forest Service nurseries particularly in the last two years is discussed. Several monitoring programs including pheromone trapping for cutworms and the cranberry girdler and trap boards for weevils are described and related to decisions on chemical control procedures, as well as cultural and natural controls.

7. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest nurseries. Industrial Forestry Association.

   Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruces.

8. Sutherland, J.R. and E. van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

   Reviews hosts, damage, life history and control of various nursery insects, including cutworms, marsh crane fly, root and vine weevils, and aphids.

Lygus Bug
(*Lygus hesperus*)

We list five references for lygus bugs; four of these cover lygus bug on conifers in the Pacific Northwest (2, 3, 4, 5). Taxonomy of the genus is discussed in one article (1). Also discussed are abundance and distribution (3), host susceptibility (5) and management of the insect by chemical and cultural means (2, 4).

1. Kelton, L.A. 1975. The Lygus bugs (Genus *Lygus* Hahn) of North America (Heteroptera: Miridae). Entomological Society of Canada, Memoir 95.

The genus *Lygus* Hahn is revised for North America. Species are redescribed, seasonal variations in size and color are discussed, and distribution maps and host plants are included. The adult males are illustrated and a key for their identification is given.

2. Overhulser, D.L., P.D. Morgan, R. Miller. 1987. Control and impact of *Lygus* damage on 1-0 Douglas-fir seedlings. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-137, p.153-157. Western Forest Nursery Council and Intermountain Nursery Association Meeting, Proceedings, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

Lygus bug feeding on 1-0 Douglas-fir significantly increases cull and the occurrence of forking at harvest. Multiple pesticide applications between July and September can reduce damage by 80-90 percent.

3. Schowalter, T.D. 1987. Abundance and distribution of *Lygus hesperus* (Heteroptera: Miridae) in two conifer nurseries in western Oregon, USA. Environmental Entomology 16:687-690.

Seasonal patterns of *Lygus hesperus* Knight abundance and distribution were observed at two conifer nurseries in western Oregon during 1985. *Lygus* abundance differed significantly among conifer seedling types (age class/species combinations) and sampling dates. Highest densities were observed in lodgepole and ponderosa pine seedlings germinated during 1985, in Douglas-fir seedlings germinated in 1984 and in late July samples. Significant interaction between seedling type and sample date reflected a shift in *Lygus* occurrence among seedling types during the growing season, especially from 1984 Douglas-fir seedlings early in the season to 1985 seedlings later in the season. This shift coincided with dispersal of the first *Lygus* generation and with pruning of the 1984 seedlings for

height control. These results indicate that *L. hesperus* abundance and distribution in conifer nurseries result from *Lygus* phenology in combination with seasonal changes in the spatial pattern of available resources. Implications for nursery management are discussed.

4. Schowalter, T.D., D.L. Overhulser, A. Kanaskie, J.D. Stein, and J. Sexton. *Lygus hesperus* as an agent of apical bud abortion on Douglas-fir nurseries in western Oregon. New Forests 1:5-15.

Lygus hesperus caused apical bud abortion in 1-0 and 2-0 Douglas-fir seedlings in forest nurseries in western Oregon. Reduction of this damage can be accomplished by introducing nursery management practices for *Lygus* control. Such practices include chemical control and modification of seedling physiology or phenology. Our results also suggest that *Lygus* management in forest nurseries must address immigration from nearby crops, especially alfalfa and cotton.

5. Schowalter, T.D. and J.D. Stein. 1987. Influence of Douglas-fir seedling provenance and proximity to insect population sources on susceptibility to *Lygus hesperus* (Heteroptera: Miridae) in a forest nursery in western Oregon, USA. Environmental Entomology 16:984-986.

The effect of *Lygus hesperus* Knight feeding on Douglas-fir seedlings was measured in seedlings representing two elevation zones, for each of two seedling age classes in a forest nursery during 1984. Damage frequency and height reduction both indicated significant effects of seed source. Examination of seedling distance from the nursery's west boundary with an alfalfa field (a major source of *L. hesperus* in the nursery) indicated a significant effect of proximity to alternate hosts. These results suggest that seedling suspectibility to damage by *L. hesperus* is a function of seedling condition and location within the vegetation matrix.

Marsh Crane Fly
(*Tipula paludosa*)

We include nine references on marsh crane fly. Although the larva of this insect is typically a pest on turf, it can also damage conifer seedlings. Five of the references deal with marsh crane fly problems on conifers in the Pacific Northwest (5, 6, 7, 8, and 9). Biology and management of the insect is covered extensively in two references (6, 9) and in lesser detail in two others (5, 8). Two papers deal with biological control (3, 4), one with insecticidal control (2), one with general management of the insect on turf (1) and one with the effects of conifer nursery soil management on the insect (7).

1. Blackshaw, R.P. 1985. A preliminary comparison of some management options for reducing grass losses caused by leatherjackets in Northern Ireland. Annals of Applied Biology. 107:279-285.

Leatherjackets can cause serious yield reductions in Northern Ireland grass. This paper considers the distribution of field population sizes derived from 19 years' data in conjunction with calculated damage functions to estimate average expected losses. Six management options were compared. These were 'No action', routine insecticide application in September or March, insecticide application in March in high risk years only, and the use of monitoring and economic thresholds in September or March. The annual expected revenues for each of these options was calculated for herbage dry-matter values of £0.01 to 0.07 kg-1. It was concluded that action against leatherjackets in September would give better returns than action in March and that the use of monitoring and spraying of only those field populations above an economic threshold gave rise to greatest revenue. An annual loss to leatherjackets in Northern Ireland of over £15 million was calculated from an assumed herbage value of £0.035 kg-1 dry matter.

2. Campbell, R.L. 1975. Insecticidal control of European crane fly in Washington. Journal of Economic Entomology 68(3):386-388.

Tipula paludosa Meigen was recently introduced into the United States, where it is a pest of turf and forages. This study showed that several insecticides can provide control in ornamental turf. The economic injury level for forage was found to be 50 larvae/

ft² (538 larvae/m²) during spring in Washington. The suggested insecticidal control on forage is methyl parathion at 0.5 lb AI/acre (0.56 kg AI/ha) applied between mid-March and mid-April.

3. Finney, J.R. and G.F. Bennett. 1984. *Heterorhabditis heliothidis*: a potential biocontrol agent of agricultural and forest pests in Newfoundland. Journal of Agricultural Entomology 1(3):287-295.

During a laboratory study in Newfoundland, Canada, two species each of Homoptera (*Aphis craccae* and a cercopid), Coleoptera (a species of *Agriotes* and *Chrysomela falsa*) and Diptera (*Tipula paludosa* and *Delia radicum*) and eight species of Lepidoptera (*Artogeia rapae, Evergestis pallidata, Croesia curvalana, Harpipteryx xylostella, Coleophora serratella, Leucoma salicis, Lambdina fiscellaria fiscellaria* and an unidentified privet leaf-roller), all of which were taken from plants of agriculture importance or forest trees, were exposed to infection by *Heterorhabditis helioithidis* at 24 degrees C. Substantial larval mortality was obtained 48 to 72 hours after exposure in most cases; pupae and adults were also killed. The effects on the individual pests are described.

4. Lam, A.B.Q. and J.M. Webster. 1972. Effect of the DD-136 nematode and of a beta-exotoxin preparation of *Bacillus thuringiensis* var. *thuringiensis* on leatherjacket (*Tipula paludosa*) larvae. Journal of Invertebrate Pathology 20(2):141-149.

A commercial preparation, IMC 10,001.1, containing the beta-exotoxin of *Bacillus thuringiensis* var. *thuringiensis*, caused the mortality of third and fourth instar larvae of (*Tipula paludosa*) in laboratory experiments. Some larvae that survived the beta-exotoxin treatment produced abnormal pupae and adults. The DD-136 strain of *Neoaplectana carpocapsae* reproduced successfully in *T. paludosa* larvae, and in the laboratory an inoculum equivalent to about 22.2 X 109 infective DD-136 larvae per acre caused a 100 percent mortality of the insect larvae 13 days after infection. However, at 0.5 and 0.25 of the above inoculum, the nematodes caused only 34 percent and 29.8 percent insect mortality, respectively. The results from a combined applica-

tion of a low dose of the beta-exotoxin preparation with a low inoculum of DD-136 suggested a possible synergistic action of the two substances and resulted in an increased insect mortality. The possible mechanisms of action of the beta-exotoxin and of DD-136 are discussed.

5. Shrimpton, G. 1985. Four insect pests of conifer nurseries. USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.119-121. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

   Four pests of conifer nurseries in British Columbia, the strawberry root weevil, tarnished plant bug, European marsh crane fly, and conifer root aphid, are described. Their general pest status, occurrence in the nurseries, life history, damage, and control are briefly discussed.

6. Shrimpton, G.W. 1983. Biology and control of some insect pests in B.C. Forest Service seedlings nurseries. M.S. Thesis, Simon Fraser University.

   The paper represents the first phase in developing an integrated pest management system for insect pests in British Columbia conifer seedling nurseries. Five important pests, species or groups are covered: cutworms (Lepidoptera: Noctuidae); the European marsh crane fly, *Tipula paludosa*; the cranberry girdler, *Chrysoteuchia topiaria*; small flies (Diptera) in container facilities and the strawberry root weevil, *Otiorhynchus ovatus*. The general pest status, life history, damage and occurrence of these pests in B.C. Forest Service nurseries particularly in the last two years is discussed. Several monitoring programs including pheromone trapping for cutworms and the cranberry girdler and trap boards for weevils are described and related to decisions on chemical control procedures, as well as cultural and natural controls.

7. Sutherland, J.R. and R.L. Anderson. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. IN: North American Forest Tree Nursery Soils Workshop, Proceedings, p.182-190. Held July 28-August 1, 1980.

Soil conditions play a major role in preventing or causing devastating losses from many nursery disease and insect problems. This paper reviews the relationships between several soil factors, cultural practices, and certain disease and insect problems.

8. Sutherland, J.R. and E. Van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

Reviews hosts, damage, life history and control of various nursery insects, including cutworms, marsh crane fly, root and vine weevils, and aphids.

9. Wilkinson, A.T.S. and H.S. Gerber. 1972. Description, life history and control of leatherjackets. British Columbia Department of Agriculture, Entomology Branch, Publication 72-5.

Leatherjackets (larvae of *Tipula paludosa*) have recently become established in the lower Frazer Valley in British Columbia, Canada, damaging seedlings and newly transplanted vegetables and flowers, as well as pasture and turf. Notes are given on the morphology, life history and control of the Tipulid and also on a method of determining (by treating sample areas with diazinon or petrol to make the larvae appear above the soil surface) whether populations are dense enough to warrant chemical control.

Matsucoccus Scale
(*Matsucoccus* spp.)

We list 15 references on Matsucoccus scale. Work on several species such as *M. resinosae* (red pine scale) on red pine in the northeastern part of the U.S. and *M. acalyptus* (pinyon needle scale) on pinyon pine in the western U.S. is included. Articles dealing with other *Matsucoccus* species on other hosts, in other parts of the U.S. or the world, are cited as well. We found only one reference to the insect on a Pacific Northwest host and that was *M. bisetosus* on ponderosa pine in northern California (1). The majority of the articles deal with the biology of the insect (1, 2, 4, 7, 8, 9, 13, 14). Two articles are first reports of the insect in new locations (5, 15). Four articles discuss management of *Matsucoccus* by chemical (12) or cultural (3, 10, 11) means. References 10 and 11 discuss results of trials to determine relative suspectibility of host species to the insect. One reference (6) covers the biology and management of pinyon needle scale in general terms.

1. Beardsley, J.W. 1968. External morphology of the adult male of *Matsucoccus bisetosus*. Annals of the Entomological Society of America 61(6):1449-1459.

   The external morphology of adult males of the pine-infesting genus *Matsucoccus* has not been studied previously in detail. The male of *M. bisetosus* Morrison is described and compared with adult males of other Coccoidea. The *M. bisetosus* male appears to be one of the least specialized of coccid males yet studied.

2. Duda, E.J. 1977. Status of the Red Pine Scale, *Matsucoccus resinosae* B. & G. (Homoptera: Margarodidae). Journal of the New York Entomological Society.

   This one-paragraph article discusses briefly the hosts, distribution and status of control of the red pine scale. Factors affecting survival during the life of the insect are described.

3. Flake, H.W., Jr. and D.T. Jennings. 1974. A cultural control method for pinyon needle scale. USDA Forest Service Research Note. Rocky Mountain Forest and Range Experiment Station. #RM-270.

Describes a simple, inexpensive cultural control method for pinyon needle scale by washing eggs off host trees. Dislodged eggs, litter, and debris are raked, bagged, and destroyed. Control must be timed to coincide with the egg stage before crawler emergence.

4. Liphschitz, N. and Z. Mendel. 1987. Historical studies of *Pinus halepensis* stem xylem affected by *Matsucoccus josephi* (Homoptera: Margarodidae). IAWA Bulletin 8(4):369-376.

   The injury caused by *Matsucoccus josephi* Bodenheimer & Harpaz to naturally and artificially infested *Pinus halepensis* Mill. was studied with special emphasis on the reaction of the cambium to the insect attack and the subsequent changes in the xylem. Scars from stem injury were easily detected macroscopically due to discoloration on the stem cross section and involve narrowing of annual rings at the injury site for several years. Microscopic sections reveal production of abnormal xylem in the injured zone, i.e., lignified parenchyma cells instead of tracheids, curved tracheids and lignified resin ducts. Histological disorganization is compared with mechanical injuries. Changes in the orientation of cells in the xylem suggest that the effect of infestation is not only mechanical; interrupted polar auxin transport into loops is probably responsible for abnormal xylem formation.

5. Loyttyniemi, K. 1978. Scale insect of the genus *Matsucoccus* (Homoptera: Margarodidae) on pine in Finland. Notulae Entomologicae 58:115-116.

   The scale insect *Matsucoccus pini* (Green) is for the first time recorded from Finland. It was found on young pine stands in several locals in South and Central Finland, often associated with *Aradus cinnamomeus* (Heteroptera).

6. McCambridge, W.F. 1974. Pinyon needle scale (*Matsucoccus acalyptus*), USDA Forest Service Pest Leaflet #148.

   The range, hosts, signs of infestation, and life history of the Pinyon needle scale, *Matsucoccus acalyptus*, are described. Natural and chemical control measures are discussed as well.

7. McClure, M.S. 1976. Colonization and establishment of the Red Pine Scale, *Matsucoccus resinosae* (Homoptera: Margarodidae) in a Connecticut plantation. Environmental Entomology 5(5):943-947.

The horizontal and vertical distributions of the red pine scale, *Matsucoccus resinosae* B and G (Homptera: Margarodidae) were studied in a 1.6 ha pure plantation of *Pinus resinosa* Ait. in Connecticut. Both cast skins of intermediate-stage larvae from the previous generation and settled first-stage larvae had a highly contagious distribution. More than 56 percent of the total number of larvae occurred in only 8 of the 40 plots. Only 23 of 80 trees supported a previous generation of the scale. Dispersal reduced the degree of contagion by 50 percent after a single generation. The densities of settled larvae and of cast skins were not correlated with the distance of trees from a previously-infested stand, but their distributions strikingly resembled the pattern of a shelter profile, characteristic of wind-dispersed insects leeward of windbreaks. A significantly greater number of settled larvae and of cast skins occurred in the lower canopy. The least number of both occurred in the upper canopy. The densities of settled larvae and of cast skins differed significantly among the 10 trees. Branch exposure did not significantly influence scale density. The occurrence of settled larvae was significantly correlated with the density of the previous generation of scale on individual branches and on trees. Examination of cast skins on dead branches can be a valuable aid in determining population levels of *M. resinosae* on red pine.

8. McClure, M.S. 1977. Population Dynamics of the Red Pine Scale, *Matsucoccus resinoae* (Homptera: Margarodidae): the Influence of Resinosis.

Density of the red pine scale, *Matsucoccus resinosae* B and G (Homoptera: Margarodidae), and the related resinosis of its host, *Pinus resinosa* Ait., in a Connecticut plantation had a profound influence on scale biology, behavior, and population dynamics. Fecundity of the fall 1975 generation was positively correlated with the density of feeding nymphs on nine trees. During development of the subsequent summer 1976 generation, the most heavily infested trees began to secrete resins

from feeding wounds. Nymphs feeding on these trees required 2 to 3 weeks longer to mature and females produced significantly fewer eggs than their mothers. Overwintering mortality was greatest among nymphs in the early substages of the first instar, and among nymphs which colonized 1- and 2-year-old growth. Since nymphal development was prolonged on heavily infested trees, a proportionately greater number of first-instar nymphs overwintered in earlier substages of development. Also, resinosis at the preferred colonization sites (3-year-old growth) on these heavily infested trees forced crawlers to settle on the less desirable young growth. Consequently, nymphs on heavily infested trees suffered a greater percent overwintering mortality than did nymphs on less heavily infested trees. Dispersal of *M. resinosae* crawlers was density-dependent.

9. McClure, M.S. 1983. Population dynamics of a pernicious parasite density dependent vitality of red pine scale. Ecology 64(4):710-718.

   The relationships between biotic and climatic factors and three parameters of fitness (survival, developmental rate, fecundity) and population density were examined for the exotic red pine scale, *Matsucoccus resinosae* (Homoptera: Margarodidae), in a plantation of red pine, *Pinus resinosa*, in Connecticut, USA, over a period of population increase and decline from 1975 to 1980. The single most important factor leading to the collapse of the red pine scale population was change in the magnitude of overwintering mortality incurred by nymphs. Natural enemies were not important to the population dynamics of *M. resinosae*. The only such species encountered, the cecidomyiid fly, *Lestodiplosis* nr. *grassator*, consumed only 5 to 7 percent of the scale ovisacs in each year, showing no response to the changes in scale population density.

10. McClure, M.S. 1985. Susceptibility of pure and hybrid stands of *Pinus* to attack by *Matsucoccus matsumurae* in Japan (Homoptera: Coccoidea: Margarodidae).

    Studies were conducted in Japan during 1984 in pure and hybrid stands of *Pinus* species of the subsection Sylvestres to

determine their relative susceptibility to *Matsucoccus matsumurae* (Kuwana). Survivorship of scale nymphs and fecundity of adults were significantly lower on the native Japanese pines *P. densiflora* and *P. thunbergiana* and on their interspecific hybrid than on several pure and hybrid pines of related exotic species. Maternal parents of Japanese species did not confer resistance upon the F1 progeny that resulted from hybrid crosses with susceptible exotic species. Overall trends in scale survivorship in 10 pure and hybrid stands suggested a chemical basis for host suitability. However, interspecific variation in bark texture and significant differences in survivorship of nymphs in exposed and protected sites on bark indicated a physical basis for host resistance as well.

11. Mendel, Z. 1984. Provenance as a factor in susceptibility of *Pinus halepensis* to *Matsucoccus josephi* (Homoptera: Margarodidae).

    International provenance trials of *Pinus halepensis* and related species, *P. brutia* and *P. eldarica*, allowed study of the relationship between seed origin of *P. halepensis* and susceptibility to the Israeli pine bast scale (*Matsucoccus josephi*, Homoptera; Margarodidae), and the infestation of *P. brutia* and *P. eldarica* by this pest. The Greek and Israeli provenances displayed a lower susceptibility to attacks by the pest than did the North African and Spanish provenances. The lower susceptibility is expressed by a higher percentage of unaffected trees, low rate of injury, and low density of *Matsucoccus ovisacs*.

12. Pierce, D.A., W.F. McCambridge and G.E. Moore. 1968. Control of pinyon needle scale with dimethoate. Journal of Economic Entomology 61(6):1697-1698.

    This paper reports on the last in a series of tests to find a control for *Matsucoccus acalyptus* Herbert. Water-emulsion formulations of 0.5 to 1.0 percent dimethoate gave similar and effective results. Addition of a surfactant did not significantly increase mortality. Proper timing is important; spray should be applied to all egg-mass concentrations when eggs begin to hatch.

13. Stephens, G.R. 1978. Effect of low temperature on survival of red pine scale *Matsucoccus resinosae* Bean and Godwin (Homoptera: Margarodidae). New York Entomological Society 86(4):323-324.

    During 1976-78, the effect of low temperature on survival of red pine scale overwintering on 4- to 6-year-old potted red pine was studied. The lack of complete mortality at prolonged low temperature indicates that this scale is capable of infesting red pine throughout southern New England and southern New York. The reduction in mortality compared to a 1957 report suggests that a more cold-hardy scale has developed during the last 20 years.

14. Stephens, G.R. and D.E. Aylor. 1978. Aerial dispersal of red pine scale *Matsucoccus resinosae* (Homoptera: Margarodidae). Environmental Entomology 7(4)556-563.

    The aerial dispersal of red pine scale, *Matsucoccus resinosae* B and G, was observed by trapping crawlers (first instars) in the open at distances as far as 180 m from the edge of an infested 4-ha, 45-year-old red pine (*Pinus resinosa* Ait.) plantation. The ratio of the settling speed of crawlers in still air to the average horizontal wind speed is crucial for predicting crawler dispersal. The measured settling speed of crawlers was 27 5 cm s-1. In the laboratory, no crawlers were removed from needles or twigs by air speeds of 5 m s-1 or less, and complete removal of all crawlers required speeds of fully 17-22 m s-1. Consistent with this difficult removal is our estimate that in the forest only ca. 5 to 25 percent of the crawlers available for dispersal at any time are actually released. Numbers of crawlers captured per unit trap area decreased rapidly in a regular pattern away from the edge of the forest.

15. Stimmel, J.F. 1981. First record of the red pine scale, *Matsucoccus resinosae* (Homoptera: Margarodidae) from Pennsylvania. Proceedings, Entomological Society Washington 83(4):804.

    The first finding of the red pine scale, *Matsucoccus resinosae*, is reported from Pennsylvania on Japanese red pine, *Pinus densiflora*.

Pine Bark Aphid
(*Pineus strobi*)

Only three references on pine bark aphid were found. The pine bark aphid only seems to be a problem on white pine (2). The other two papers discuss the biology of the aphid. There are no references from the Pacific Northwest.

1. Johnson, W.T. and H.H. Lyon. 1976. Insects that feed on trees and shrubs: an illustrated practical guide. Cornell University Press.

Discusses life cycles and hosts and includes numerous color photos for various insects, including *Chionaspis pinifoliae, Adelges cooleyi, Pineus strobi,* and *Otiorhynchus* spp.

2. Rogers, D., C. Doggett, and H. Barron. 1984. Growth loss and mortality of white pine nursery stock caused by pine bark aphids after field planting. Tree Planters' Notes 35(4):14-15.

Outplantings of 2-0 white pine seedlings heavily infested with pine bark aphids were compared with outplantings of uninfested seedlings in a 1980-81 study. After two growing seasons, there was no statistically significant difference in mortality between heavily infested and uninfested seedlings. There was a significant difference in growth, however, with the uninfested seedlings averaging 11 percent greater growth than the infested seedlings.

3. Sluss, T.P. and B.A. Foote. 1973. Biology and immature stages of *Leucopis pinicola* and *Chamaemyia polystigma* (Diptera: Chamaemyiidae). Canadian Entomologist 105:1443-1452.

The life cycles and larval feeding habits of *Leucopis* (*Neoleucopis*) *pinicola* and *Chamaemyia polystigma* were studied in northeastern Ohio. The larval stages of *L. pinicola* are predators of the pine bark aphid, *Pineus strobi.* Probably there are only two generations a year, and overwintering occurs as mature larvae or pupae that are in diapause. Larvae of *C. polystigma* prey on the blue grass mealybug, *Heterococcus nudus,* that infests perennial rye grass, *Lolium perenne.* This species has three generations a

year and overwinters as diapausing mature larvae and pupae. The eggs, three larval instars, and pupa of both species are described and illustrated.

Pine Needle Scale

(*Chionaspi pinifoliae*)

We include 18 references on pine needle scale which are evenly divided over a range of topic areas. The majority of articles deal with chemical (3, 7, 11, 12, 18) and biological (2, 5, 6, 8, 9, 14) control of *Phenacaspis (chionaspis) pinifoliae.* Several describe the biology of the insect (5, 6, 10, 13, 15, 16), one is a detection report (1), and two discuss general biology and management (4, 17). Only one reference describes a problem with pine needle scale in the Pacific Northwest (17); the majority of the work has been done on various pine species in southern California or eastern United States. This insect causes damage on lodgepole pine, mugho pine, red pine, Jeffrey pine and Scots pine. It is normally of little consequence in Pacific Northwest conifer nurseries.

1. Dahlsten, D.L. and R. Garcia. 1969. Insect problems in forest recreation areas. California Agriculture 23(7):4-6.

   Discusses some insects whose increasing abundance in California forests may reflect the adverse effect of incursions by man, notably the unsightly and damaging *Phenacaspis (Chionaspis) pinifoliae* on *Pinus contorta,* an outbreak of which in the South Lake Tahoe area may have been partly attributable to a program of mosquito control with malathion fog.

2. DeBoo, R.F. and J.A. Weidhaas, Jr. 1976. Plantation research: XIV. Studies on the predation of pine needle scale, *Phenacaspis pinifoliae* (Fitch), by the coccinellid, *Chilocorus stigma* (Say). Canadian Forestry Service, Chemical Control Research Institute, Report CGX-119.

   Predator/prey relations were studied in 1963-65 in a Christmas tree plantation of *Pinus sylvestris,* averaging 2 meters tall, in New York during a natural invasion of *Chilocorus stigma.* Additional information was gained from controlled field tests,

laboratory tests and a study of three isolated *P. mugo* with scale infestation. The prey and predator species had two generations per year which were well synchronized. About 86 percent of the trees were infested by the scale in each year and most showed moderate infestation, with large numbers of scales occurring only on branches of the lower crown quarter. The coccinellid consumed 99 percent of the prey in controlled field experiments regardless of prey density, but tended to die out on lightly infested trees. On the isolated *P. mugo*, predation was light and the beetle did not become established.

3. Hay, C.J. 1976. Fumigation effects of SO_2 on pine needle scale infestations on eastern white pine. American Phytopathological Society, Proceedings 3:305.

   Eastern white pine seedlings infested with pine needle scale (*Chionaspis pinifoliae*) were fumigated with 0.5 ppm SO_2 for 6 hours per day and 5 days per week for 10.5 weeks over the second and part of the third generations of the scale. Scale density of the control second generation increased more (3.5X) than the SO_2-treated population (1.35X), but length of mature females and fecundity second generation females were similar. It is concluded that *P. pinifoliae* is tolerant to SO_2 and could thrive in polluted areas where P. strobus is also tolerant. Variation in tree response to SO_2 was noted.

4. Johnson, W.T. and H.H. Lyon. 1976. Insects that feed on trees and shrubs: an illustrated practical guide. Cornell University Press.

   Discusses life cycles and hosts and includes numerous color photos for various insects, including *Chionaspis pinifoliae*, *Adelges cooleyi*, *Pineus strobi*, and *Otiorhynchus* spp.

5. Luck, R.F. and D.L. Dahlsten. 1974. Bionomics of the pine needle scale, *Chionaspis pinifoliae*, and its natural enemies at South Lake Tahoe, California. Annals of the Entomological Society of America 67:309-316.

   Reports a study at four infested sites, between 1969 and 1971, showing that two distinct scale populations occur sympatrically, one on *Pinus contorta* and one on *P. jeffreyi*. The *P. contorta*

population is parthenogenetic and overwinters as eggs, while the *P. jeffreyi* population is bisexual and overwinters as gravid females. It is not certain whether the populations are ecotypes or distinct species. Five natural enemies associated with the scale are reported: populations on *P. contorta* are parasitized by the chalcidoids *Prospaltella bella* and *Physcus howardi*, while the scale on *P. jeffreyi* is parasitized by *Achrysocharis phenacapsia*. These differences persist even in mixed stands.

6. Luck, R.F. and D.L. Dahlsten. 1975. Natural decline of a pine needle scale (*Chionaspis pinifoliae* [Fitch]) outbreak at south Lake Tahoe, California following cessation of adult mosquito control with malathion. Ecology 56:893-904.

The population dynamics of a pine needle scale infestation were studied at South Lake Tahoe, California from 1969 to 1971. A uniparental population on lodgepole pine, and a biparental population on Jeffrey pine declined dramatically during the study period. The dominant mortality factors for the lodgepole pine population were crawlers which failed to settle, parasitization by *Prospaltella bella*, predation by *Chilocorus orbus* var. *monticolus* and *Cryptoweisia atronitens*, and an unknown mortality of adult female scale. In the Jeffrey pine population, the dominant factors were crawlers which failed to settle, unknown mortality of immature scale, and predation by the same coccinellid species. An intrageneration, intertip analysis of scale populations on lodgepole pine revealed that predation destroyed a constant proportion of the scale population in all study areas. Furthermore, parasitization by *P. bella* showed a within-tip response that increased (proportionately) with decreasing needle age. In the Jeffrey pine site, intertip analysis indicated predation upon a constant proportion of the scale population. *Achrysocharis phenacapsia*, like *P. bella*, increased its percent parasitism with decreasing needle age. Laboratory bioassays in which adult diaspid scale parasitoids were exposed to foliage collected from areas fogged for mosquito control indicated insecticide residues were present. The results of the bioassays, the location of the infested area, and field observations on arthropod associations implicated the mosquito control program as causal to the scale outbreak at South Lake Tahoe.

7. Martel, P. 1972. Malathion and dimethoate in the control of the pine needle scale *Phenacaspis pinifoliae* (Homoptera:Diaspididae). Annales de la Societe Entomologique du Quebec 17(1):20-23.

Seasonal populations of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), on mugho pines, has been reduced by 99.5 percent after a single application of malathion. Dimethoate, used as a systemic treatment on the ground in mid-July, when the scales were fixed upon the needles, gave similar results with 100 percent reduction over the check.

8. Martel, P. and M.L. Sharma. 1970. Notes on *Microweisea marginata*, a predator of *Phenacaspis pinifoliae*. Annales de la Societe Entomologique du Quebec 15(2):61-65.

Briefly discusses field observations on bionomics, and laboratory observations on predation by larvae and adults of this coccinellid to evaluate its importance for the control of *Phenacaspis (Chionaspis) pinifoliae*.

9. Martel, P. and M.L. Sharma. 1975. Parasites of *Phenacaspis pinifoliae* in the Sherbrooke area, Quebec. Annales de la Societe Entomologique du Quebec 20(1):11-14.

Quantitative studies were made on infestations of *Phenacaspis pinifoliae* at two sites on shoots of *Pinus sylvestris* and *P. mugo* respectively. Three known species of parasite were found, but the incidence of parasitization was very low (0.4 percent and 0.9 percent respectively).

10. Martel, P. and M.L. Sharma. 1968. Studies on the biology and ecology of *Phenacaspis pinifoliae* in Quebec. Phytoprotection 49(1):19-25.

Studies on the evolutionary cycle of *P. pinifoliae* were made. The five development stages of the insect occurred from June 12 to August 22. The natural mortality may be as high as 33 percent, the parasitism and predation being of the rate of 0.45 percent and 1.30 percent respectively.

11. Nielsen, D.G. 1970. Host impact, population dynamics, and chemical control of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), in central New York. Ph.D. dissertation. Dissertation Abstracts 31B(12):7350.

    Insect-host plant relationships, population dynamics, and chemical control of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), were investigated in order to facilitate an integrated control program for this pest of ornamental pines.

12. Nielsen, D.G. and N.E. Johnson. 1972. Control of the pine needle scale in central New York. Journal of Economic Entomology 65:1161-1164.

    Supracide®, oxydemetonmethyl, disulfoton, monocrotophos, ethion-oil, and carbofuran at different rates were evaluated for control of *Phenacaspis (Chionaspis) pinifoliae* on *Pinus sylvestris*, *P. mugo*, and *P. resinosa*. Sprays directed against mature second-stage nymphs or virgin adults were more effective than sprays directed against crawlers. Possibilities of integrated control of the pest are discussed.

13. Nielsen, D.G. and N.E. Johnson. 1973. Contribution to the life history and dynamics of the pine needle scale, *Phenacaspis pinifoliae*, in central New York. Annals of the Entomological Society of America 66:34-43.

    Intensive sampling of *Pinus resinosa*, *P. sylvestris* and *P. mugo* var. *mughus* trees near Ithaca, NY, showed that the change in population in 1 year (2 generations) ranged from a decrease of 50 percent on one *P. resinosa* to a 3- to 5-fold increase on two *P. sylvestris* and a 4- to 20-fold increase on two *P. mugho* var. *mughus*. Factors associated with the much lower survival of the spring than of the summer generation of *Phenacaspis (Chionaspis) pinifoliae*, and with the differences in population change recorded between the one indigenous and two exotic host species, are discussed. Host species had a marked effect on survival of the spring but not the summer generation. Parasites and predators were associated with all the scale populations studied, but their effect was not significant until after injury had reached economic proportions.

14. Roberts, F.C., R.F. Luck, and D.L. Dahlsten. 1973. Natural decline of a pine needle scale population at South Lake Tahoe. California Agriculture 27:10-12.

Describes investigations of a pine needle scale outbreak over 1,300 acres in vicinity of South Lake Tahoe. Discusses biocontrol options and gives results of surveys in 1970-72.

15. Walstad, J.D. 1972. Impact of pine needle scale, *Phenacaspis pinifoliae* (Fitch), on the physiology of Scots pine, *Pinus sylvestris* L. Ph.D. dissertation. Dissertation Abstracts 32B:5852.

This dissertation abstract discusses the manner in which *Phenacaspis pinifoliae* injures its host and the extent of this injury as expressed by alterations in host (Scots pine) physiology.

16. Walstad, J.D., D.G. Nielsen, and N.E. Johnson. 1973. Effect of the pine needle scale on photosynthesis of Scots pine. Forest Science 19:109-111.

Reports studies at Cornell University, NY, on 3-year-old *Pinus sylvestris* artificially infested with *Phenacaspis pinifoliae*. The insect's stylets were shown to enter the needle through stomata and to terminate in mesophyll tissue. The percent reduction in chlorophyll content and in net photosynthetic rate were approximately equal to the percent of foliage surface area covered by scale insects.

17. Wood, R.O. and D.A. Ross. 1972. Pine needle scale and black pine leaf scale in British Columbia. Canadian Forestry Service, Forest Pest Leaflet 40.

Deals briefly with *Phenacaspis (Chionaspis) pinifoliae* and *Nuculaspis californica*, their preferred hosts, distribution, biology, and control.

18. Yu, S.J., N.E. Johnson, and D.G. Nielsen. 1970. Influence of soil moisture conditions on effectiveness of systemic insecticides in American elm and red pine. Journal of Economic Entomology 63(3):824-826.

Oxydemetonmethyl and disulfoton were applied as concentrates to stems or as dilute emulsions to the foliage of red pine seedlings grown in the greenhouse under two soil moisture regimes. The greatest mortality of pine needle scales, *Phenacaspis pinifoliae* (Fitch), occurred on those plants grown under the drier conditions. Analysis of parent compound and metabolite of oxydemetonmethyl showed that the plants growing under dry conditions retained the insecticide at higher levels for longer periods than those growing under moist conditions. Somewhat different results obtained with the two-spotted spider mite, *Tetranychus urticae* Koch. on American elm. Suggested reasons for the different responses are given.

Root Weevils
(*Otiorhynchus* spp.)

A total of 12 references are listed and 5 of these apply directly to the Pacific Northwest (1, 5, 6, 10, 12). There are many weevil species and the hosts are not limited to conifers. The references are scattered across a range of topics. Five discuss management strategies and biology or identification of the insect (5, 6, 7, 10, 12) and one deals with impact on host (4). Cultural control (11), biological control (1, 8) and chemical control (2, 9) are covered in various articles. Reference 3 is an illustrated guide that provides some information on the biology of root weevils.

1. Capizzi, J. and M. Morris. 1988. Nematode research in control of root weevils. Northwest Lookout 21(2):56.

   In 1986, a study was conducted to evaluate the effectiveness of using entomogenous nematodes for control of stawberry root weevil (*Otiorhynchus ovatus*). The objectives of the experiment were to test the effectiveness of three factors in controlling the root weevil populations: 1) Entomogenous nematode species, 2) application rate, and 3) application timing.

2. De Clercq, R. and H. Casteels, 1986. Control of the black weevil *Otiorrhynchus sulcatus* (Coleoptera: Curculioinidae). Hortscience 21(3 Sect. 2):731.

Endosulfan, parathion, carbofuran, carbosulfan, etrimfos, and deltamethrin were tested against the *Otiorrhynchus sulcatus*. All gave good results against the adults, but only etrimfos was effective against the first stage of the larvae.

3. Johnson, W.T. and H.H. Lyon. 1976. Insects that feed on trees and shrubs: an illustrated practical guide. Cornell University Press.

   Discusses life cycles and hosts and includes numerous color photos for various insects, including *Chionaspis pinifoliae*, *Adelges cooleyi*, *Pineus strobi*, and *Otiorhynchus* spp.

4. Parry, W.H. 1981. Weevils (Coleoptera: Curculionidae) on foliage of Sitka spruce (*Picea sitchensis*) in northeast Scotland. Scottish Forestry 35(2):96-101.

   Observations on young Sitka spruce trees near Aberdeen indicated that five weevil species (*Otiorrhynchus scaber*, *O. singularis*, *Phyllobius argentatus*, *Polydrusus cervinus*, and *Strophosomus melanogrammus*) were commonly present. Laboratory observations showed that damage consisted of needle consumption which was not economically important at the insect levels observed in the field. Such damage could reach economic levels in forest nurseries.

5. Shrimpton, G.W. 1983. Biology and control of some insect pests in B.C. Forest Service seedlings nurseries. M.S. Thesis, Simon Fraser University.

   The paper represents the first phase in developing an integrated pest management system for insect pests in British Columbia conifer seedling nurseries. Five important pests, species, or groups are covered: cutworms (Lepidoptera: Noctuidae); the European marsh crane fly, *Tipula paludosa*; the cranberry girdler, *Chrysoteuchia topiaria*; small flies (Diptera) in container facilities; and the strawberry root weevil, *Otiorhynchus ovatus*. The general pest status, life history, damage, and occurrence of these pests in B.C. Forest Service nurseries, particularly in the last two years, is discussed. Several monitoring programs, including pheromone trapping for cutworms

and the cranberry girdler and trap boards for weevils, are described and related to decisions on chemical control procedures, as well as cultural and natural controls.

6. Shrimpton, G. 1985. Four insect pests of conifer nurseries. USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.119-121. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

   Four pests of conifer nurseries in British Columbia, the strawberry root weevil, tarnished plant bug, European marsh crane fly, and conifer root aphid, are described. Their general pest status, occurrence in the nurseries, life history, damage, and control are briefly discussed.

7. Shrimpton, G. 1987. Some insect pests of conifer seedlings in British Columbia. USDA Forest Service, Intermountain Research Station, General Technical Report INT-137, p.128-130. Western Forestry Nursery Council and Intermountain Nursery Association Meeting, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 12-15, 1986, Tumwater, Washington.

   Girdling damage to conifer seedlings caused by the cranberry girdler, *Crambus nevadellus*, the European marsh crane fly, and adult weevils is described. A monitoring program for fungus gnat populations in greenhouses is also discussed.

8. Simons, W.R. 1982. Biological control of *Otiorrhynchus sulcatus* with Heterorhabditid nematodes in a glasshouse. Netherlands Journal of Plant Pathology 87(4):149-158.

   Heterorhabditis spp. found in dead larvae of *O. sulcatus*, was tested for its efficacy as a biological control agent of this insect in glasshouse experiments. In a preliminary test, all weevil larvae were killed in pots with primula, 88 percent in straw-

berry, and 50 percent in cyclamen. In a second test with strawberry plants good results were obtained when the nematodes were applied at about the hatching time of the weevil eggs. At a dosage of 100 nematodes/cm^2 of soil area, 90 to 97 percent of the larvae were killed and 90 percent of the plants remained undamaged. A dosage of 50 nematodes/cm^2 produced roughly the same level of larval mortality, but left 30 percent of the plants damaged. Both early and late application of nematodes protected the plants insufficiently, because too many larvae survived. In a third test with strawberry, cyclamen, and primula, soil treatment and 50 to 100 nematodes/cm^2 gave comparable results at both application times, i.e., 1 and 3 weeks after hatching of the weevil eggs. In strawberry, 100 percent of the larvae were killed and all plants remained in good condition. Also in cyclamen, nearly all larvae were killed and the plants remained in good condition, although the root systems had less fine roots in comparison with control plants without insects. In primula, 4 to 12 percent of the weevil larvae survived; up to 20 percent of the plants died, indicating that soil structure, soil moisture, and condition of the plants have important impacts on the control results. A dosage of 25 nematodes/cm^2 appeared to be too low in all cases. The results of these experiments open new perspectives for control of the black vine weevil in glasshouses.

9. Smith, D.N. 1955. Use of chlordane at Duncan Forest Nursery. Department of Agriculture, Canada, Division of Forest Biology, Bi-Monthly Progress Report 11(2):2.

   The preventative use of the soil insecticide chlordane against the strawberry root weevil is being continued at a rate of 10 lb/acre applied prior to seeding of beds.

10. Solomonson, M.H. 1980. Insect pests of Pacific Northwest forest nurseries. Industrial Forestry Association.

    Provides descriptions of damage, identification keys, and chemical and other cultural control methods for several insect pests. Root weevils, cutworms, aphids, cranberry girdlers, and

the Cooley gall adelgid are discussed. Hosts mentioned are Douglas-fir, Engelmann, and Sitka spruce.

11. Sutherland, J.R. and R.L. Anderson. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. IN: North American Forest Tree Nursery Soils Workshop, Proceedings, p.182-190. Held July 28-August 1, 1980.

    Soil conditions play a major role in preventing or causing devastating losses from many nursery disease and insect problems. This paper reviews the relationships between several soil factors, cultural practices, and certain disease and insect problems.

12. Sutherland, J.R. and E. Van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests and Canadian Forestry Service, Joint Report 12.

    Reviews hosts, damage, life history, and control of various nursery insects, including cutworms, marsh crane fly, root and vine weevils, and aphids.

Annotated Bibliography

Weeds

Weeds

General References

We list 52 references on weed control in conifer nurseries. Literature prior to 1972 is not included. References are from a wide variety of places. Fourteen are from Oregon, Washington and Idaho (8, 9, 10, 11, 14, 21, 28, 33, 34, 35, 36, 41, 48, 49); 15 are from the southeastern United States (12, 18, 19, 29, 30, 32, 39, 42, 43, 44, 45, 46, 47, and 52); 12 are from the midwest and northeastern United States (1, 3, 4, 5, 13, 16, 17, 20, 25, 26, 27, 40); 3 are from California and the southwest (2, 24 and 38); and 10 are from outside of the United States, mostly from Canada (6, 7, 8, 15, 22, 23, 31, 37, 50, 51).

Three publications deal with the economics of weed control (14, 42, 46). Seven papers cover cultural control methods (6, 9, 10, 11, 25, 26, 34); 2 discuss biological control methods (14, 34); and 6 cover control by fumigation (6, 9, 10, 11, 26 and 34). The remainder report control by chemical herbicides; toxicity to the crop and to the weed species is usually mentioned. The herbicides most frequently referenced are bifenox, diphenamide, glyphosate, napropamide, and oxyfluorfen. One manual has been included (38) which deals with herbicides and weed control in ornamental nurseries.

Indexes of crop species and weed species, with pertinent references for each species, follow the annotated references listed below.

1. Abrahamson, L.P. and K.F. Burns. 1979. Herbicide screening for weed control in western forest nurseries - Great Plains segment. State University of New York, Syracuse, Applied Forestry Research Institute, AFRI Research Report 41.

   The objectives of this study were to evaluate the effect of various herbicides on three genera of conifers and five of hardwoods, and on herbaceous vegetation in first-year seedling beds. Diphenamid, trifluralin, DCPA, and chloramben were tested at six nurseries in the Midwest. Weeds were collected from each plot, counted, and/or weighed after drying for 72 hours at 65 degrees C to estimate weed control. Herbicidal damage to conifers and hardwoods at the end of the first growing season was evaluated using a ten-point rating scale.

2. Agamalian, H.S. 1985. Developing weed control systems for conifer seedlings. Western Society of Weed Science, Proceedings 38:164-167.

Several herbicides were tested in a 3-year trial on a sandy loam soil where the main weed species were *Malva parviflora, Senecio vulgaris, Medicago polymorpha, Capsella bursa-pastoris,* and *Erodium botrys* for weed control in *Pinus radiata* and *Pseudotsuga menziesii* nurseries. 1 to 2 lb prometryn/acre applied preemergent showed good selectivity to the conifer species and improved weed control; selectivity remained excellent when 2 to 4 lb bifenox, 4 lb diphenamid, or 0.5 to 1.0 lb oxyfluorfen/acre were added. Postemergence application of 1 to 2 lb prometryn or 2 to 4 lb bifenox/acre when trees were 8 to 10 inches tall resulted in acceptable tree tolerance. Oxyfluorfen caused some phytotoxicity, with *P. radiata* more sensitive than *P. menziesii.*

3. Ahrens, J.F. 1974. Selectivity of glyphosate and asulam in ornamental plantings and Christmas trees. Northeastern Weed Science Society, Proceedings 28:361-368.

Trials were carried out in dormant conifers, actively growing seedlings, newly planted conifers, 3-year-old nursery plants, and container-grown plants in many woody species, mainly conifers. Selective rates centered around 3 to 4 lb for asulam and 0.5 to 1.0 lb/acre for glyphosate; these rates controlled succulent annual weeds, but glyphosate was more effective against perennial weeds such as *Cerastium vulgatum, Agropyron repens* and *Taraxacum officinale.* Glyphosate has no residual activity, but asulam controlled *Digitaria* species for 4 to 6 weeks. Both herbicides affected the growing points of weeds and woody plants; woody plants showed a wide range of tolerance to the herbicides. Conifers generally showed greater tolerance than deciduous plants. Conifers were more tolerant when dormant or fully mature than when growing rapidly. Asulam at 3 lb/acre was usually less toxic to growing woody plants than glyphosate at 0.5 lb/acre, but autumn applications of glyphosate at 0.5 to 1.0 lb/acre on dormant conifers controlled perennial grasses and blackberry *(Rubus* spp.), with only slight growth suppression in *Taxus cuspidata.* Autumn treatments with glyphosate could be used to control perennial weeds in nurseries; glyphosate at 0.5 kg/ha could be used in established conifers during the growing season. Asulam could also be used in nurseries during the growing season. The

temporary growth suppression of woody ornamentals caused by these herbicides is an added advantage to landscape plantings.

4. Ahrens, J.F. 1978. Preemergence and postemergence herbicides for nursery plantings. Northeastern Weed Science Society, Proceedings 32:290.

   In two separate field experiments over a 4-year period, herbicides were applied over newly planted nursery stock on a sandy loam soil and repeated the following spring. Oats were sown each autumn to evaluate the effects on cover crop. Oryzalin at 2 or 4 lb and oxadiazon 3 or 4 lb/acre controlled 90 percent or more of all weeds during each season and seriously reduced oat cover crops in autumn without injury to juniper (*Juniperus horizontalis plumosa compacta*), yew (*Taxus cuspidata*), forsythia (*Forsythia intermedia*), or white pine (*Pinus strobus*). Best residual control of weeds a year after application was obtained with oryzalin. Simazine at 1.5 lb/acre + oryzalin controlled *Taraxacum officinale* and *Panicum dichotomiflorum* better than oryzalin alone but injured forsythia. Alachlor granular at 4 to 8 lb + simazine granular 1.5 lb/acre controlled most annual weeds for 2 to 4 months, and injured forsythia but not white pine, yew or juniper. Asalam at 3 lb + oxadiazon at 2 lb/acre gave postemergent control of *Digitaria* spp., *Mollugo verticillata, Erigeron canadensis,* and *Erigeron annuus.*

5. Ahrens, J.F. 1980. Effects of surfactant or preemergence herbicides on the selectivity of asulam and glyphosate in woody plants. Northeastern Weed Science Society, Proceedings 34:330-333.

   Phytotoxicity to weeds and nursery plants from surfactant additions to sprays of asulam at 2 to 4 lb and glyphosate 0.124 to 0.5 lb/acre was determined in field experiments. Adding either the surfactant X-77 or a simazine at 2 lb + oryzalin 3 lb/acre mixture, or both, improved control of large crabgrass (*Digitaria sanguinalis*) and horseweed (*Conyza canadensis*) by asulam at 1.67 lb/acre without injury to Japanese yews (*Taxus cuspidata*) or Andorra junipers (*Juniperus horizontalis* var. *plumosa*). At higher rates of asulam, however, these additives made the sprays injurious to junipers. Adding only simazine to the asulam sprays improved weed control without plant injury. The surfactant MON 0011 added to low rates of glyphosate applied in June markedly im-

proved control of large crabgrass, fall panicum (*Panicum dichotomiflorum*) and common lambsquarters (*Chenopodium album*). In another trial at higher rates of glyphosate (up to 1.5 lb/acre) applied in September, MON 0011 increased injury to dormant white pine (*Pinus strobus*). Simazine did not affect injury to pines by glyphosate in September.

6. Aldhous, J.R. Nursery practice. Forestry Commission (Great Britain), Bulletin 43, p.92-106.

   Reviews various methods of weed control in nurseries, including handweeding, mechanical methods, mulches, and chemicals.

7. Au, P.N. 1985. Preemergent herbicide trial in white spruce at Pine Ridge Forest Nursery. USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.77-79. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings of Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

   0.2 g propyzamide, 0.6 g chlorthal-dimethyl, 0.24 g bifenox and 0.5 g napropamide/m^2 were tested for weed control in a white spruce seedbed. *Hieracium* spp., *Chenopodium album, Polygonum convolvulus* and grasses were the main weeds present. All herbicides significantly reduced the number of weeds, although propyzamide was less effective than the other treatments; all except propyzamide increased white spruce seedling stem height and dry weight.

8. Bandeen, J.D., J.V. Parochetti, G.F. Ryan, B. Maltais, and D.V. Peabody. 1979. Discovery and distribution of triazine-resistant weeds in North America. Weed Science Society of America, Abstracts of Meeting, 1979:108-109.

   Failure to control *Senecio vulgaris* with simazine was observed in 1968 in a nursery near Olympia, Washington. Subsequent testing of the progeny showed resistance to injury from simazine and atrazine. These have now spread into all three northwest counties. In 1978, resistant *S. vulgaris* became a serious problem in maize in Fraser Valley in British Columbia. Triazine-resistant *Amaranthus retroflexus* was found in 1968 near Stanwood, Wash-

ington, and resistant *Chenopodium album* near Lynden, Washington in 1973. These two have spread in the maize-growing areas of Whatcom, Skagit, Snohomish, and King Counties. In the East, triazine-resistant *C. album* was documented in 1976 in the Ontario counties of Bruce, Elgin, Norfolk, and Oxford; it has also been found near Kentville, Nova Scotia. Triazine-resistant *A. retroflexus*, found near Westminster, Maryland, in 1974, has spread in six counties of western Maryland and southern Pennsylvania. Another resistant species, found in maize near Paris, Ontario, was identified as *Chenopodium strictum* var. *glaucophyllum*. All resistant species have first appeared as scattered plants in fields where a triazine herbicide has been used for more than 6 years and where no inter-row cultivation had been done. These weed escapes in maize fields produced seed which was spread by harvesting equipment or through livestock feed and manure return.

9. Cooley, S.J. 1982. Soil solarization in a forest nursery for the control of nursery pests. USDA Forest Service, Pacific Northwest Region, Forest Pest Management.

A new soil treatment, solarization, was compared to soil fumigation and no treatment in an eastern Oregon conifer nursery. Seedling survival, weed reduction, and populations of soil fungi and nematodes were evaluated in all treatments. Fumigation resulted in superior survival and stand of ponderosa pine seedlings during the first 10 weeks after emergence. Seedling survival in solarized areas was similar to that in check areas. Weed control was best in fumigated and poorest in check plots. Both fumigation and solarization resulted in lowered populations of *Fusarium* spp. and several groups of nematodes when sampled immediately after treatment. Soil temperatures at depths of 5, 15, an 30 cm were at least 10 degrees higher during solarization than temperatures in nonsolarized soil. Operational use of solarization cannot be recommended until further solarization trials show levels of pest reduction and seedling survival similar to those seed with fumigation. The causes for poor performance in solarized plots are discussed.

10. Cooley, S.J. 1985. Evaluation of solarization and fumigation at the J. Herbert Stone Nursery. USDA Forest Service, Pacific Northwest Region.

    Fumigation and solarization were compared at the J. Herbert Stone Forest Nursery in southwest Oregon for disease and weed control. Fumigation resulted in significantly reduced levels of weeds and disease. Solarization, while reducing the number of weeds, did not decrease disease severity. Possible reasons for poor disease control with solarization are discussed.

11. Cooley, S.J. 1985. Solarization in two Pacific Northwest forest nurseries. IN: USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.45-48. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings, Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

    Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

12. Dill, T.R. and M. C. Carter. 1973. Preemergence weed control in southeastern forest nurseries. Weed Science 21(4):363-366.

    Weed control trials were conducted on *Pinus taeda* or *P. elliottii seedbeds* at 12 locations in the southeastern U.S. Good weed control was obtained from prometryne at 2.2 and 4.5 kg/ha; diphenamid at 4.5 and 9 kg/ha; trifluralin at 1.1 and 2.2 kt/ha; and GS-16068 at 2.2 and 4.5 kg/ha as preemergence applications immediately followed by irrigation. Diphenamid and trifluralin treatments were not injurious to either pine species at either rate. GS-16068 was only slightly injurious at the high rate at one location. Prometryne was injurious at two locations at the high rate and at one location at the low rate.

13. Dobson, J.B., T.R. Peoples, A.M. VanCantfort, and D. VanWinkle. 1985. AC 252,925: a new multipurpose herbicide for vegetation control. Northeastern Weed Science Society, Proceedings 39:228.

    The new broad-spectrum herbicide AC 252,925 (imazapyr) for use in nurseries, Christmas tree plantations, and industrial sites is described. It is suitable for control of problem weeds such as *Rhus* spp., *Rubus* spp., *Campsis radicans, Rosa multiflora, Acer* spp., *Fraxinus* spp., *Populus* spp. and *Prunus* spp.

14. Dutton, D.W. 1982. Chinese weeder geese: do they or do they not weed in the nursery? IN: Western Nurserymen's Conference, Proceedings, 1982, p.44-48.

    Discusses Chinese weeder geese as a method of weed control during tree production operations at the U.S. Forest Service Wind River Nursery, Carson, Washington. Describes cost effectiveness, advantages, and disadvantages of this method of control.

15. Esau, R. 1982. Herbicide investigations in coniferous tree nurseries in Saskatchewan and Alberta. IN: Canadian Forestry Service, Northern Forest Research Centre, Information Report NOR-X-241, p.68-74. Intermountain Nurserymen's Association Meeting, Proceedings, 1981 edited by R.F. Huber. Held August 11-13, 1981, Edmonton, Alberta.

    Provides a brief overview of current research in weed control for the production of conifer seedlings and transplants in Alberta and Saskatchewan. Glyphosate, oxyfluorfen, bifenox, sethoxydim, and fluazifop methyl were tested and results are summarized.

16. Frank, J.R. and J.A. Simon. 1981. Glyphosate and paraquat effectiveness in woody nursery stock. Weed Science 29(4):455-461.

    In May 1976, 2- and 3-year-old plants of six woody ornamentals were planted in the field and treated with one, two, or three annual directed applications of glyphosate at 2.2 and 4.5 kg/ha and paraquat at 0.6 and 1.1 kg/ha. Three applications of glyphosate or paraquat were required to control weeds for the entire growing season. Late-season applications of glyphosate in 1977

controlled weeds in early 1978. Glyphosate at 4.5 kg/ha applied twice a year for 3 years controlled *Taraxacum officinale, Plantago lanceolata, Rumex obtusifolius,* and *R. acetosella.* Three annual applications gave 100 percent control of *Calystegia sepium, Cirsium arvense, Polygonum pensylvanicum,* and *Amaranthus albus.* Crop size, crop quality, and marketability of the six ornamentals were not adversely affected by either herbicide. Two or three applications of glyphosate at 2.2 kg/ha or two treatments at 4.5 kg/ha increased plant size of andorra junipers (*Juniperus horizontalis*). Three treatments of glyphosate at 2.2 kg/ha also increased the size of dwarf Japanese yews (*Taxus cuspidata*) and two treatments at 4.5 kg/ha increased the size of boxleaf Japanese holly (*Ilex crenata*).

17. Fretz, T.A. and W.J. Sheppard. 1980. Prodiamine: a promising herbicide for weed control in container nursery production. HortScience 15(4):489-490.

    Preemergence applications of prodiamine-2 percent G at 1.7, 3.4, 6.7, and 13.4 kg a.i./ha effectively controlled *Digitaria sanguinalis, Amaranthus retroflexus,* and *Chenopodium album* for up to 113 days after application. No injury was noted on the 11 woody ornamentals tested, including *Cotoneaster dammeri, Juniperus horizontalis,* and *Ligustrum obtusifolium.*

18. Gjerstad, D.H. and D.B. South. 1981. Preemergence weed control in loblolly, slash, shortleaf, and eastern white pine nursery seedbeds. Canadian Journal of Forest Research 11(4):848-853.

    Pine seedling tolerance to preemergence applications of herbicides was examined in field experiments conducted on *Pinus taeda, P. elliottii, P. echinata,* and *Pinus strobus* at six southern forest nurseries in 1976 and 1977. Herbicides suitable for preemergence use were bifenox at 3.4 kt/ha; diphenamid at 4.5 kg/ha; oxyfluorfen at 0.3, 0.6 and 1.1 kg/ha; HOE-22870 at 1.1 and 2.2 kg/ha; and prometryn at 1.1 kg/ha. Seedling injury to some species was caused by trifluralin at 1.1 kg/ha; butralin at 3.4 kg/ha; perfluidone at 1.7 kg/ha; butralin at 3.4 kg/ha plus bifenox at 3.4 kg/ha; napropamide at 3.4 kg/ha; propazine at 3.4 kg/ha; and a combination of napropamide at 1.7 kg/ha plus bifenox at 3.4 kg/ha.

19. Gjerstad, D.H., D.B. South, and R.H. Crowley. 1979. Effect of selected herbicides on production of southern pines (*Pinus* spp.) in nursery seedbeds. Weed Science 27(2):173-177.

    Regional pine seedling tolerance experiments were conducted on 5 pine species at 10 forest nurseries in 1974. Similar studies in 1975 included four pine species at nine locations. From these studies, herbicides appearing safe for preemergence use are bifenox at 1.7, 3.4, and 6.7 kg/ha; butralin at 2.2, 3.4, 4.5 and 6.7 kg/ha; napropamide at 1.1 kg/ha plus bifenox at 3.4 kg/ha; dinitramine at 0.37 and 0.74 kg/ha; diphenamid at 4.5 kg/ha; trifluralin at 1.1 kg/ha; and profluralin at 1.1 and 2.2 kg/ha. Southern pine seedling tolerance to oryzalin was unacceptable at 1.1 and 2.2 kg/ha. Napropamide severely stunted seedlings at 6.7 kg/ha but affected seedlings only slightly at 3.4 kg/ha.

20. Gouin, F.R. 1977. Controlling rip-shins (brambles) and mugwort with glyphosate. Northeastern Weed Science Society, Proceedings 31:328.

    Eradication of brambles (*Rubus* spp.) and mugwort (*Artemisia vulgaris*) is essential before preparing nursery soil for planting. Glyphosate was applied to brambles growing in full sun and under partial shade at 1.2, 2.4, and 4.8 kg in 557 litres of water/ha at 20- to 30-day intervals starting in mid-June, July, August, September, and October. Only brambles sprayed in June with 4.8 kg/ha appeared to have been injured. July applications of 2.4 and 4.8 kg/ha resulted in visible permanent injury to all brambles sprayed. Visible permanent damage was observed on brambles treated in August and September at all rates. Brambles growing in partial shade appeared to be as susceptible to glyphosate as those in full sun. July, August, and September treatments resulted in complete control of *A. vulgaris*.

21. Haglund, W.A., K.W. Russell, and R.C. Holland. 1981. Moss control in container-grown conifer seedlings. Tree Planters' Notes 32(3):27-29.

    Seedlings grown in styroblock containers were sprayed with 8 surfactants, or combinations of surfactant and the fungicide captan. Phytotoxicity and moss control were recorded 7 and 14

days after treatment and trees were measured after 30 to 60 days. The least phytotoxic surfactant was X77; this had no significant effect on height, stem diameter, and total weight of *Pseudotsuga menziesii* or *Tsuga heterophylla* seedlings. Almost complete moss control was achieved with 40 to 80 lb captan and 2.5 to 10 gal X77 in 100 gal water applied to *Abies procera* seedlings; treatment with the highest concentration (80 lb captan and 10 gal X77) was only phytotoxic when the seedlings already had foliar injury. In *Tsuga heterophylla* treatment with captan and X77 at various concentrations caused tree injury only at 89 to 90 degrees F, but not at 60 to 65 degrees F.

22. Hall, M. 1986. Postemergence weed control in a radiata pine nursery with four selective herbicides. Australian Forestry 49(3):155-159.

    Azioprotryne, a mixture of propazine and chlorthal, fluazifop-butyl, and haloxyfop-ethoxyethyl were each applied to radiata pine seedbeds 2 weeks after pine emergence, while the latter two herbicides were also applied 10 weeks after emergence. Aziprotryne at 3.0 and 6.0 kg a.i./ha was active on broadleaved weeds, in this case mainly *Polygonum aviculare*, but at 3.0 kg/ha, aziprotryne did not significantly reduce grass dry weight or numbers. Fluazifop-butyl at 0.85 and 1.70 kg a.i./ha and haloxyfop-ethoxyethyl at 0.42 and 0.84 kg/ha provided excellent control of small grass weeds when applied 2 weeks after pine emergence, but failed to control more established grasses when applied at 10 weeks. Neither fluazifop-butyl nor haloxyfop-ethoxyethyl had any effect on broadleaved weeds. It is suggested that a mixture of one of these chemicals with a suitable rate of aziprotryne may provide an effective broad-spectrum postemergence herbicide treatment for radiata pine seedbeds.

23. Hallett, R.D. and T.W. Burns. 1983. Postemergence application of herbicides to control weeds in containerized tree seedling crops. Canadian Forestry Service, Maritimes Forest Research Centre, Technical Note 77.

    Modown® (bifenox), Roundup® (glyphosate), Goal® (oxyfluorfen), Garlon® (triclopyr), and 2,4-D were applied singly and in combination to one white spruce and four black spruce crops, aged 2 to 14 months at the Fraser Tree Nursery. Roundup® alone or in

combination with Modown® resulted in excellent weed control and did very little damage to seedlings. Modown® alone did not control all weeds, particularly poplar seedlings. Goal®, Garlon®, and 2,4-D alone or in combination damaged tree seedlings and gave erratic weed control. None of the herbicide treatments controlled liverworts. It is concluded that very low rates of Roundup® provide effective and safe weed control in containerized spruce seedling crops when applied in late summer or autumn.

24. Heidmann, L.J. and S.M. Haase. 1985. Herbicides for controlling weeds at the Albuquerque Forest Tree Nursery. IN: USDA Forest Service, Intermountain Research Station, General Technical Report INT-185, p.91-94. Western Forest Nursery Council and Intermountain Nurseryman's Association, Proceedings of Combined Meeting, edited by T.D. Landis. Held August 14-16, 1984, Coeur d'Alene, Idaho.

    In 1982, a study was initiated to test oxyfluorfen, bifenox, and propazine for controlling grasses and forbs in ponderosa pine nursery beds. Propazine was highly toxic to pine seedlings. Oxyfluorfen at a rate of 0.5 lb a.i./acre controlled vegetation without damage to tree seedlings.

25. Hildebrand, D.M. 1985. Soil solar heating for control of damping-off fungi and weeds at the Colorado State Forest Service Nursery. Tree Planters' Notes 36(1):28-34.

    Sample plots were covered for 55 days with 2-mil clear polyethylene for solar heating in July 1982. Soil samples were collected from treated and untreated plots in June, August, and the following April. There were significant reductions in damping-off (*Pythium* spp. reduced 60 percent on average, and *Fusarium* spp. reduced 74 percent). Germination of weed seeds from soil samples was significantly reduced, and weed cover was reduced by 97 percent on solar plots.

26. Hildebrand, D.M. 1985. Soil solar heating for reduction in populations of *Pythium*, *Fusarium*, nematodes, and weeds at the U.S. Forest Service Bessey Tree Nursery, Halsey, Nebraska. USDA Forest Service, Rocky Mountain Region, Technical Report R2-34.

    Three plots were covered with 0.02 mm clear polyethylene tarp for solar heating for 8 weeks (June 21 to August 17) in summer 1983, and three plots were left fallow as checks. In spring 1984, three plots were fumigated with methyl bromide/chloropicrin prior to planting all plots with lodgepole pine seed. Soil samples were taken before and after soil treatments. Populations of *Pythium* spp. were significantly reduced by solar heating, but returned to high levels by spring, probably due to the effects of the sudangrass winter cover crop. Fumigation was less effective than solar heating in reducing populations of *Pythium* spp. in samples taken immediately after treatment. Reductions in populations of *Fusarium* spp. by solar heating were not statistically significant, and in samples taken immediately after treatment, reductions due to fumigation were similar to those due to solar heating. Weed populations were significantly reduced by solar heating, but returned to pre-treatment levels by the following spring. In samples taken immediately after treatment, solar heating was as effective as fumigation for weed control. No significant effects on lodgepole pine seedling survival resulted from any of the treatments. The winter cover crop grew more lush and darker green in solar plot locations than in the surrounding check area.

27. Kuhns, L.J., G. Twerdok, and C. Haramaki. 1983. Pre- and postemergence herbicides for use on conifer seedbeds. Northeastern Weed Science Society, Proceedings, 37:310-311.

    Weed control with 1.5 kg bifenox/ha preemergence was inadequate and not improved by raising the rate; control with oxyfluorfen preemergence was rate-dependent, being marginal at 0.55 kg/ha and good at 1.1 kg. Control of red clover and grasses was greatly enhanced when these compounds were applied in mixtures with 2.2 or 4.4 kg napropamide/ha, but these treatments were not tolerated by Colorado spruce. Douglas-fir, Fraser fir, and white pine were tolerant of all preemergent treatments. When bifenox and oxyfluorfen were applied as split treatments or followed by 0.27 or 0.55 kg fluazifop or sethoxydim/ha postemergence, Colorado spruce remained the most susceptible species, but injury was within commercially acceptable levels.

28. McDonald, S.E.; Isaacson, J.A.; Fisher, B.E. 1974. Using diphenamid herbicide for seedbed weed control cuts hand-weeding labor 75 percent. Tree Planters' Notes 25(3):15-17.

    Six herbicides (Dymid®, simazine, Dacthal®, Amiben®, Treflan®, and Casaron®) were applied to seedlings of *Pinus contorta, P. ponderosa, Picea engelmannii, Larix occidentalis, Pseudotsuga menziesii,* and *Abies grandis* at the Coeur d'Alene Nursery in 1969. Dacthal® , Dymid®, and Treflan® were well tolerated, but Amiben®, simazine, and Casaron® killed large percentages of the seedlings. In 1970, the three non-toxic herbicides were tested in semi-production to measure weed control effectiveness. Because of variability of weed distribution, weed control effectiveness data was difficult to interpret, but we concluded that Dymid® and Dacthal® are effective and safe weed control agents to use in this nursery.

29. Milbocker, D.C. and H. Wilson. 1975. Dinitroanilines as nursery herbicides. Southern Nurserymen's Association, Proceedings, Research Conference 20:131.

    The following herbicides were compared for weed control in established Japanese holly (*Ilex crenata*): trifluralin at 1 lb/acre, dinitramine and butralin at 0.9 lb/acre and profluralin, nitralin and fluchloralin all at 1 lb/acre. No treatment injured the holly after 7 months and all controlled *Stellaria media. Lamium amplexicaule* was satisfactorily controlled by all compounds except trifluralin and butralin, but evening primrose (*Oenothera laciniata*) which developed a strong taproot that successfully penetrated the herbicide layer, will not easily be controlled by these compounds.

30. Milbocker, D.C. and H. Wilson. 1975. Promising herbicides for nursery weed control. Southern Nurserymen's Association, Proceedings, Research Conference 20:132-133.

    Among herbicides tested, methazole, incorporated at 2 lb/acre caused immature leaf drop in Japanese holly (*Ilex crenata*), and its margin of selectivity seemed generally slight; the compound did not control *Stellaria media* or *Lamium amplexicaule* satisfactorily. Alachlor at 4 lb/acre controlled both weeds well, and oxadiazon at 2 lb/acre gave excellent control of *L. amplexicaule,* which was resistant to trifluralin at 1 lb/acre and diphenamid at 4 lb/acre.

31. Moon, D. 1984. New herbicides prove successful in the war on weeds. Nurseryman and Garden Centre 172(8):26-28.

Herbicide trials are reported for woody plant nurseries with simazine-resistant populations of groundsel (*Senecio vulgaris*). Crop species were as follows: mixed apple rootstocks, budded in the previous year, and 1 m tall when treated; *Tilia platyphyllos* cv. *Rubra* seedlings 2 m tall; *Thuja plicata* 23 cm tall; and *Chamaecyparis lawsoniana* cv. *Lanei* 30 cm tall. In February, plots received simazine (as 2.5 kg of 50 percent product/ha) or atrazine (as 2.25 litre Gesaprim®) alone or plus napropamide (9 or 18 litre Devrinol®), oxyfluorfen (as 2 or 4 litre Goal 2E®), oxadiazon (4 or 8 litre Ronstar®) or oxyfluorfen + propyzamide granules (60 or 120 kg RH 666). All treatments except oxyfluorfen + propyzamide granules at 60 kg/ha significantly reduced groundsel populations assessed in June compared with simazine or atrazine along. Napropamide at both rates, and oxyfluorfen at 4 litre/ha, were particularly effective. In October, all treatments had controlled autumn seedlings of groundsel; the oxyfluorfen spray and the granules of oxyfluorfen + propyzamide were best. In addition, overwintered perennial weeds, which were a problem on *Tilia* and *Chamaecyparis* plots, were checked by all treatments and dandelion and perennial nettle were controlled by napropamide and oxyfluorfen.

32. Munson, R.H., J.R. Gipson, and J.R. Abernathy. 1983. Efficacy and phytotoxicity of herbicides in field nurseries. Southern Weed Science Society, Proceedings, 36th Annual Meeting, p. 175-176.

In 1982, double rate oryzalin gave best weed control of *Euphorbia supina*, *Amaranthus* species, *Kochia scoparia*, *Physalis* species, wheat, *Solanum elaeagnifolium*, and *Cynodon dactylon* in *Pinus thunbergiana*, *Quercus texana*, *Lagerstroemia indica*, and *Euonymus japonica 'Aureo-variegata'*. Normal rate oryzalin was next best, and metolachlor, S-734, and trifluralin were equally less effective. No treatment was phytotoxic. In a bioassay 120 days after treatment, wheat seeds germinated normally in all treatments but growth was stunted in the double rate oryzalin plots.

33. Newton, M., J. Lemhouse, and R.K. Hermann. 1977. Chemical weed control in western conifer nursery beds — research and program development. IN: Western Forest Nursery Council and Intermountain Nurserymen's Association, Proceedings, 1976.

Experiments were done on 1-year-old Douglas-fir in seedbeds and on newly germinated Douglas-fir in greenhouses. Recommendations are made for herbicides that can be safely used at each stage of seedling development.

34. Owston, P.W. and L.P. Abrahamson. 1984. Weed management in forest nurseries. IN: Forest nursery manual: production of bareroot seedlings, p.193-202. M.L. Duryea; T.D. Landis, editors. Martinus Nijhoff/ Dr W. Junk Publishers.

Discusses biology of weeds, methods of control (physical, biological, and chemical), and herbicide characteristics, effectiveness, phytotoxicity, and use.

35. Parker, R. and J.H. Griffin. 1981. Canada thistle control. Washington State University, Cooperative Extension Service, Extension Bulletin 780.

Lists chemical and cultural methods for control of *Circium arvense* in various crops, including nursery stock and orchards.

36. Peabody, D.V. and R. Parker. 1985. Blackberry control with systemic herbicides. Washington State University, Cooperative Extension Service, Extension Bulletin 1327.

Herbicides that have resulted in control of *Rubus* species include: amitrole, AMS, dicamba, fosamine, glyphosate, and trichlopyr. Rates, methods, precautions, and restrictions for each are reviewed.

37. Powell, J.M. 1975. Use of Gramoxone® to control mosses and liverworts in greenhouse pots. Environment, Canada, Forestry Service, Bi-monthly Research Notes 31(5):35-36.

Describes trials to assess the ability of Gramoxone® (paraquat) to control moss and liverwort growth on pots containing transplanted *Pinus contorta* seedlings 0.5 m high, kept for 20 months in a greenhouse. The herbicide was applied at 9 ml/l or 4.5 ml/l; both concentrations proved equally effective. One month after treatment, 85 percent of the mosses and 100 percent of the liverworts had been killed, and little regrowth occurred in the next 7 months.

38. Rice, R.P., Jr. 1986. Nursery and landscape weed control manual. Thomson Publications, Fresno, California.

Describes all aspects of weed control. Contains chapters on importance of weed control, weed biology, weed control methods, chemical weed control, herbicides and the environment, specialized application equipment, herbicide safety, ornamental weed identification guide, and ornamental herbicide guide. It also contains a useful index to herbicides by weeds controlled and index to herbicides by ornamental species.

39. Rogers, N.K. 1981. Weed control in field-grown conifers. Southern Weed Science Society, Proceedings, 34:128.

In a commercial nursery of conifers at Waynesboro, Virginia, oxyfluorfen at 1 lb/acre gave 95 percent control of grasses after 14 weeks in *Pinus strobus*, while in *Picea abies* oxyfluorfen at 0.25 lb resulted in 99 percent weed control after 6 weeks. BAS 9025 at 1 and 2 lb/acre gave 100 percent control of grasses. At Midlothian, Virginia, metolachlor at 2 lb/acre, oryzalin 1.5 lb, and oxyfluorfen 1 and 2 lb gave complete control of *Stellaria media* and *Lamium amplexicaule* after 7 weeks.

40. Ryker, R.A. 1981. Evaluation of herbicides for weed control in Rocky Mountain - Great Basin nurseries. IN: USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-109, p.22-28. Intermountain Nurseryman's Association and Western Forest Nursery Association, Proceedings of Combined Meeting. Held August 12-14, 1980, Boise, Idaho.

Four herbicides (bifenox, DCPA, napropamide, and diphenamid) were tested for effectiveness in reducing the handweeding time required for weed control in nursery seedbeds. Handweeding was reduced by 50 to 80 percent, depending on herbicide and nursery. Tolerance of these herbicides by five species of pine, Engelmann and blue spruces, and Douglas-fir are summarized.

41. Sloan, J.P. and R.H. Thatcher. 1988. Oxyfluorfen shows promise in lodgepole pine seedbeds. Tree Planters' Notes 39(2):3-9.

The herbicide oxyfluorfen was applied at 0.75 and 1.5 lb/acre to *Pinus contorta* nursery beds. First-year treatments reduced seedlings heights. Second-year applications had little effect on seedling heights or densities. Oxyfluorfen reduced weeding times by 76 percent.

42. South, D.B. 1986. Herbicides for southern pine seedbeds. Southern Journal of Applied Forestry 1-:152-157.

Prior to 1970, nursery managers relied primarily on methyl bromide fumigation, mineral spirits, and hand weeding for weed control. Since 1970, various herbicides have been registered for use prior to sowing, just after sowing, or after emergence of the pine seedlings. It has been estimated that for all nurseries in the South, use of these herbicides has reduced weed control costs by over $2 million per year. This paper describes some of the herbicides that have been registered for use in southern pine nurseries.

43. South, D.B. and D.H. Gjerstad. 1980. Oxyfluorfen: an effective herbicide for southern pine nurseries. Southern Journal of Applied Forestry 4:36-39.

Preemergence tests over a 3-year period at 11 forest nurseries indicate that oxyfluorfen at 0.5 or 1.0 lb a.i./acre provides good weed control without causing injury to *Pinus taeda, P. elliottii, P. echinata, P. palustris, P. virginiana,* and *P. strobus.* Postemergence applications of oxyfluorfen at 0.5 or 1.0 lb/acre controlled small succulent weeds at nine forest nurseries without injuring 4- to 8-week-old seedlings of loblolly and slash or 29-week-old longleaf pine.

44. South, D.B. and D.H. Gjerstad. 1982. Postemergence control of grasses with selective herbicides in pine and hardwood seedbeds. Tree Planters' Notes 33(1):24-28.

In 1980, seedbeds of *Pinus taeda, P. strobus, Liriodendron tulipifera, Juglans nigra, Platanus occidentalis, Fraxinus pennsylvanica,* and *Quercus nigra* were given 1 of 8 herbicide treatments: (1) and (2) difenopenten at 0.5 or 1.0 kg/ha a.i. with surfactant; (3), (4), (5), and (6) RO-13-8895 at 0.25, 0.5, 1.0 or 2.0 kg/ha a.i. with surfactant; and (7) and (8) sethoxydim at 0.5 or 1.0 kg/ha a.i. with crop oil. Seedlings were at least 4 weeks old at treatment, and weed control ratings were recorded 1 to 4 weeks after treatment. No injury was recorded to any tree species, and weed control ratings were 70 to 92 percent for Bermudagrass (*Cynodon dactylon*) and 65 to 100 percent for crabgrass (*Digitaria sanguinalis).* The numbers of plantable seedlings produced per square meter were significantly increased for *Pinus taeda* with treatments (1), (2), (7), and (8) (other treatments not tested) and for *L. tulipifera* with treatments (1), (2), and (7) (only (8) also tested).

45. South, D.B. and D.H. Gjerstad. 1983. Postemergence weed control in loblolly, slash, longleaf, and eastern white pine nursery seedbeds. Canadian Journal of Forest Research 13:1257-1261.

Pine seedling tolerance to postemergence applications of herbicides was examined in field experiments conducted on *Pinus taeda, P. elliottii, P. palustris,* and *P. strobus* at eight southern forest nurseries in 1976 and at five nurseries in 1977. Herbicides suitable for postemergence use are (in kg/ha): bifenox, 2.2 and 4.5;

acifluorfen, 0.3 and 0.6; oxyfluorfen, 0.3 and 0.6; oxadiazon, 2.2 and 4.4; napropamide, 1.7 and 3.4; butralin, 3.4 and 6.7. Seedling injury to some species was caused by chloramben at 4.5 and 9.0 kg/ha and prometryn at 1.1 and 2.2 kg/ha. Chlorosis was noted with 2.2 kg/ha of perfluidone.

46. South, D.B., D.H. Gjerstad, and R.H. Crowley. 1978. Bifenox: a promising new herbicide for southern pine nurseries. Southern Journal of Applied Forestry 2(1):11-14.

Preemergence tests over a 3-year period at 11 forest nurseries indicate that bifenox at 1.5, 3, or 6 lb a.i./acre provides good weed control without causing injury to *Pinus taeda, P. elliottii, P. echinata,* and *P. palustris.* The lower rates did not harm *P. strobus,* but the 6 lb/acre rate reduced seedling density. At most locations, bifenox at 3 lb/acre provided longer lasting weed control than diphenamid at 4 lb/acre. Postemergence applications of bifenox at 2 or 4 lb/acre controlled small succulent weeds at eight forest nurseries without injuring 3- to 10-week-old seedlings of loblolly, slash, and eastern white pine.

47. South, D.B., D.H. Gjerstad, and T.E. White. 1978. Effects of bermudagrass on production of loblolly pine seedlings in a Louisiana nursery. Tree Planters' Notes 29(4):20.

Describes deleterious effects of bermudagrass (*Cynadon dactylon*) on the production of loblolly pine seedling at Columbia, Louisiana. The presence of bermuda grass caused a 66 percent reduction in plantable seedlings and a 44 percent reduction in fresh weights.

48. Stewart, R.E. 1977. Herbicides for weed control in western forest nurseries. IN: Western Society of Weed Science, Proceedings 30:78-89.

The results reported here are the initial phase of a 3-year research program designed to identify promising herbicides, develop data for product registration, and demonstrate safe and effective weed control practices. The objectives of this study are to evaluate the effect of various herbicides on herbaceous weeds and on first-year seedlings of *Pseudotsuga, Abies, Pinus, Tsuga,* and *Sequoia* at western forest nurseries.

49. Stewart, R.E. and P.W. Owston. 1978. Evaluation of six herbicides for weed control in Pacific coast forest nurseries. IN: Western Forest Nursery Council and Intermountain Nurseryman's Association, Conference and Workshop Proceedings, 1978, p.B127-133, edited by R.W. Gustafson. Held October 1978, Eureka, California.

A study was installed at 14 Pacific coast forest nurseries during 1977 to evaluate weed control and conifer phytotoxicity of bifenox, butralin, DCPA, diphenamid, napropamide, and hexazinone on first-year seedlings of 9 species of conifers. Postseeding sprays were more effective than postgermination sprays for total-season weed control. This reflects the greater number and vigor of weeds germinating and emerging earlier in the season and suggests that postseeding weed control is critical. All herbicides except napropamide produced effective weed control (at least 70 percent reduction in weed dry weight) when applied as postseeding or postseedings + postgermination sprays.

50. Tait, F., P. Biggin, and W.J. McCavish. 1980. A review of trials with diphenamid in forest nurseries in Great Britain. IN: Conference on weed control in forestry, proceedings, p.159-166. Held April 1-2, 1980, University of Nottingham, England.

Trials and practice since 1971 have shown that diphenamid is well tolerated in the seedbed stage by the conifers and some of the broadleaved species grown commercially in British forest nurseries. It is particularly safe for use in Sitka spruce and lodgepole pine. Preemergence or postemergence application can be used, with the former giving the best weed control. Diphenamid can reduce by 75 percent the time spent hand weeding. Repeat doses to prolong weed control can be made if needed in the season. Diphenamid is also an alternative herbicide for use in transplant lines where simazine-susceptible cultivars are being grown.

51. van den Driessche, R. and M.B. Balderston. 1974. Trials with selective herbicides in Forest Service nurseries. British Columbia Forest Service, Research Note 61.

A number of trials were made to find selective herbicides suitable for use in conifer nurseries in British Columbia between 1969 and 1973. Three triazine herbicides—propazine, prometone, and

prometryne—proved useful on seedbeds. Propazine, applied 28 days after germination, caused little damage to seedlings up to a rate of 1.12 kg active ingredient (a.i.) per hectare, and gave useful weed control at 0.56 kg a.i. per hectare. Prometone was similar to propazine, but tended to cause slightly more damage to seedlings. Prometryne was suitable for application the day after sowing at rates up to 1.12 kg a.i. per hectare. The postemergence oil spray, AWK, gave useful weed control, but must be applied immediately after emergence, before seed coats of conifer are shed. A substituted urea herbicide, linuron, applied at 0.56 kg a.i. per hectare to Douglas-fir seed beds, 28 days after germination, gave little crop damage and useful weed control. Linuron could not be used on other species in the early stages, but could be used at 0.56 kg a.i. per hectare, generally after the first growing season was finished. Similarly a fourth triazine herbicide, simazine, could be used at rates up to 1.12 kg a.i. per hectare, generally after the first growing season was finished.

52. Weatherspoon, D.M. and R.E. Wooten. 1981. Glyphosate tank mixtures in nurseries and Christmas trees. Southern Weed Science Society, Proceedings 34:130-137.

In several tests in North Carolina, glyphosate at 3 lb/acre gave adequate control of most weeds in field nursery transplants and Christmas tree plantations, while very satisfactory results were obtained in most cases with oryzalin and simazine each at 2 to 3 lb/acre in tank mixtures with glyphosate. An additional application of glyphosate was sometimes necessary for satisfactory control of woolly croton (*Croton capitatus*), horsenettle (*Solanum carolinense*), Bermuda grass (*Cynodon dactylon*), trumpet creeper (*Campsis radicans*), and *Rubus* spp.

Index by Crop: Conifers

Common Name	Scientific Name	Reference Number
Andorra Juniper	*Juniperus horizontalis plumosa*	3, 4, 5
Austrian Pine	*Pinus nigra*	1, 39
Basswood	*Tilia platyphylos*	31
Black Hills Spruce	*Picea glauca*	1
Colorado Blue Spruce	—	
	Picea pungens	1, 15, 27, 40
Douglas-fir	*Pseudotsuga menziesii*	2, 5, 21, 27, 28, 40, 49
Eastern Red Cedar	*Juniperus virginiana*	1
Engelmann Spruce	*Picea engelmannii*	28, 40
Fraser Fir	*Abies Frazeri*	27
Grand Fir	*Abies grandis*	28
Japanese Yew	*Taxus cuspidata*	3, 4, 5
Loblolly Pine	*Pinus taeda*	48
Lodgepole Pine	*Pinus contorta*	1, 28, 41, 49, 50
Monterey Pine	*Pinus radiata*	2, 22
Mugo Pine	*Pinus mugo mughus*	5
Noble Fir	*Abies procera*	21, 49
Northwest spp.	—	49, 50
Norway Spruce	*Picea abies*	39
Pines	*Pinus* spp.	40
Ponderosa Pine	*Pinus ponderosa*	1, 24, 28, 49
Port-Orford-Cedar	*Chamaecyparis lawsoniana*	31
Scotch Pine	*Pinus sylvestris*	5, 15
Sitka Spruce	*Picea sitchensis*	51
Southern Conifers	—	53
Southern Pines	*Pinus* spp.	1, 12, 18, 19, 42, 43, 44, 45, 46, 47
Western Hemlock	*Tsuga heterophylla*	21, 50
Western Larch	*Larix occidentalis*	28
Western Red Cedar	*Thuja plicata*	31
Western White Pine	*Pinus monticola*	27
White Pine	*Pinus strobis*	3, 4, 5, 18, 39, 45
White Spruce	*Picea glauca*	3, 5, 7, 15
Woody Ornamentals	—	16

Index by Crop: Hardwoods

Common Name	Scientific Name	Reference Number
East Coast Ornamentals	—	5, 17
Forsythia	*Forsythia intermedia*	4, 5
Green Ash	*Fraxinus pennsylvanica*	1
Honeysuckle	*Lonicera* spp.	1
Mulberry	*Morus* spp.	1
Poplar	*Populus* spp.	
Privet	*Ligustrum ovalifolium*	5
Russian Olive	*Elaeagnus angustifolia*	1
Siberian Pea	*Caragana* spp.	1
Southern Hard-wood Species	—	32, 44, 53
Woody Ornamentals	—	24

Index by Chemical

Chemical Name	Trade Name	Abstract Number
Trifluralin	Treflan®	1, 12, 18, 19, 29, 32, 42, 49
DCPA	—	1, 40, 49, 50
Chloramben	—	1, 46, 49
Chloroxuron	—	1, 49
Napropamide	Devrinol®	1, 2, 7, 18, 19, 27, 40, 42, 46, 49, 50
Butralin	—	1, 18, 19, 29, 49, 50
Bifenox	Modown®	1, 2, 7, 15, 18, 19, 23, 24, 27, 40, 42, 46, 47, 49, 50
Oxyfluorfen	Goal®	1, 2, 15, 19, 23, 24, 27, 35, 36, 39 41, 42, 43, 46
Oxadiazon	Ronstar®	1, 4, 30, 42, 46, 49
Glyphosate	Roundup®	1, 3, 5, 15, 16, 20, 23, 35, 36, 42, 49, 53
Diphenamid	Enide®	1, 2, 12, 18, 19, 28, 40, 42, 49, 50, 51
Prometryn	Caparol Prometryn®	2, 12, 19, 42, 46, 52
Asulam	Asulox®	3, 4, 5
Simazine	—	3, 4, 28, 51, 52, 53
Oryzalin	—	3, 4, 18, 32, 39, 49, 53
Alachlor	—	4, 30
Pronamide	Kerb®	7, 52
Chlorthal Dimethyl	Dacthal®	7, 22, 28, 52
GS 16068	—	12
AC 252 925	Arsenal®	13
Sethoxydim	Poast®	15, 27, 42, 44
Fluazifop Methyl	—	15
Paraquat	Gromoxone®	16, 35, 37
Prodiamine	—	17
Plofluralin	—	9, 18
HOE 22870	—	19, 49
Propazine	—	19, 22, 24, 52
Captan	—	21
Triazine	—	52
Azioprotryne	—	22
Fluazifop-Butyl	Fusilade®	22, 42
Haloxyfop-		

Index by Chemical

Chemical Name	Trade Name	Abstract Number
Ethoxyethyl	—	22
Triclopyr	—	36
Dymid	—	28
Amiben	—	28
Treflan	—	28
Casaron	—	28
Dinitroanaline	—	29
Nitralin	—	29
Fluchloralin	—	29
Methazole	—	30
Metolachlor	—	32, 39
EPTC	Eptam Genept®	42
Difenopentin	—	44
—	RO-13-8895®	44
Aciflourfen	—	46
Perfluidone	—	46, 49
Velpar	—	1, 49
Chlorpropham	—	49, 52
Cyperquat	—	1, 49
Methazole	—	49
Hexazinone	—	50
S-734	—	32
Basamid	—	15
24-D	—	35
Dicamba	—	35, 36
Picloram	—	35
Bentazon	—	35
Amitrole	—	35, 36
MCPB Amine	—	35
AMS	—	36
Fosamine	—	36
Propham	—	52
Linuron	—	52

Index by Weeds

Common Name	Scientific Name	Reference Number
Annual Fleabane	*Erigeron annuus*	4
Ash	*Fraxinus* spp.	13
Bermuda Grass	*Cynadon dactylon*	48
Blackberry	*Rubus* spp.	5, 12, 20, 36
Broadleaf Weeds	—	39, 41
Buckwheat	*Fagopyrum* spp.	
Burclover	*Medicago polymorpha*	2
Campus	*Campus radicans*	13
Canada Thistle	*Cirsium arvense*	15, 35
Carpet Weed	*Mollugo verticillata*	4, 12, 43, 45
Cherry	*Prunus* spp.	13
Clover	*Trifolium* spp.	40
Common Speedwell	*Veronica officinalis*	5
Crab Grass	*Digitaria* spp.	1, 3, 4, 5, 12, 17, 27, 43, 46
Cress	—	39
Dandelion	*Taraxacum officinale*	4, 5, 15, 40
Dog Fennel	*Eupatorium capillifolium*	12
East Coast Weeds	—	16
Fall Panicum	*Panicum dichotomiflorum*	3, 4
Field Bindweed	*Convolvulus arvensis*	40
Filaree	*Erodium botrys*	2, 39, 40
Flixweed	*Descurainia sophia*	15
German Moss	—	39
Goose Grass	*Flusine indica*	43, 46
Grasses	Family Gramineae	7, 12, 14, 24, 39, 40, 41, 42, 43, 44, 48
Groundsel	*Senecio vulgaris*	2, 8, 15, 31, 50
Hawks Beard	*Crepis* spp.	7, 15
Henbit	*Lamium amplexicaule*	12
Horseweed (Mare's Tail)	*Conyza canadensis*	1, 3
Horseweed	*Erigeron canadensis*	4, 5
Knotweed	*Polygonum* spp.	1, 40
Lambsquarter	*Chenopodium album*	1, 3, 7, 8, 12, 15, 17, 40, 43, 45
Little Mallow	*Malva parviflora*	2

Index by Weeds

Common Name	Scientific Name	Reference Number
Liverworts	—	37
Maple	*Acer* spp.	13
Mosses	—	37
Mouseear Chickweed	*Cerastium vulgatum*	5
Mugwort	*Artemisia vulgaris*	20
Northwest Weeds	—	34, 40, 49
Oldfield Toadflax	*Linaria canadensis*	5
Orchard Grass	*Dactylis glomerata*	5
Perennial Sowthistle	*Sonchus avensis*	15
Pigweed	*Amaranthus* spp.	1, 8, 12, 17, 24, 40, 43, 46
Populus	*Populus* spp.	13
Purslane	*Portulaca oceracea*	1, 12, 15, 40, 43, 45
Quackgrass	*Agropyron repens*	5
Ragweed	*Ambrosia artemisufolia*	12
Rhus	*Rhus* spp.	13
Russian Pigweed	*Axyris amaranthoides*	15
Sheeps Sorrel	*Rumex acetosella*	50
Shepherds Purse	*Capsella bursa-pastoris*	2, 40, 50
	Chenopodium strictum	8
Southeastern Weeds	—	12, 29
Southern Weeds	—	32, 44
Southwestern Weeds	—	24
Spurge	*Euphorbia* spp.	1, 5
Stink Grass	*Eragrostis cilianensis*	5
Stinkweed	*Thalspi arvense*	5
Summer Cypress	*Kochia* spp	1
Tansy	*Tanacetum* spp.	40
Wild Rose	*Rosa multiflora*	13
Yellow Foxtail	—	27
Thistle	—	40

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